DEMAND SIDE MANAGEMENT PLAN
FOR
GUJARAT ELECTRICITY BOARD

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The Project Team

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Executive Summary

Traditionally, in order to meet new demand for electricity, the approach followed has been to build new power plants and thus augment generating capacity. Two major drawbacks of this approach are the necessity of investing large financial resources, and the degradation of the environment.

Demand Side Management (DSM) is an alternative approach which has gained favour in recent years. This approach looks at augmenting capacity by way of saving on energy use by the existing consumers. Every MW which is saved from the existing load, is free to be delivered to new customers.

This study researches the various DSM options available to the Gujarat Electricity Board (GEB), and comes up with a plan to implement selected options in GEB's service area. In 1994-95, GEB had an installed capacity of 4372.48 MW, generated 21987.12 GWh, and sold 19865.00 GWh to the ultimate consumers in its service area.

There were five energy efficient technologies (EETs) which were identified to be implemented in Gujarat, and they are:

1. Replacement of 40 W tubelights with 36 W tubelights in the industrial sector.
2. Replacement of standard efficiency ceiling fans with high efficiency fans in the domestic sector.
3. Replacement of standard efficiency motors with high efficiency motors in the industrial sector.
4. Replacement of standard efficiency pumps with high efficiency pumps in the industrial sector.
5. Replacement of magnetic ballasts with electronic ballasts in the industrial sector.

If all the above EETs were to be adopted, their total long term savings potential based on the current energy consumption in Gujarat, would be of the order of 240 GWh (Table 1).

Table 1: Economic Potential of Selected Energy Efficient Technologies

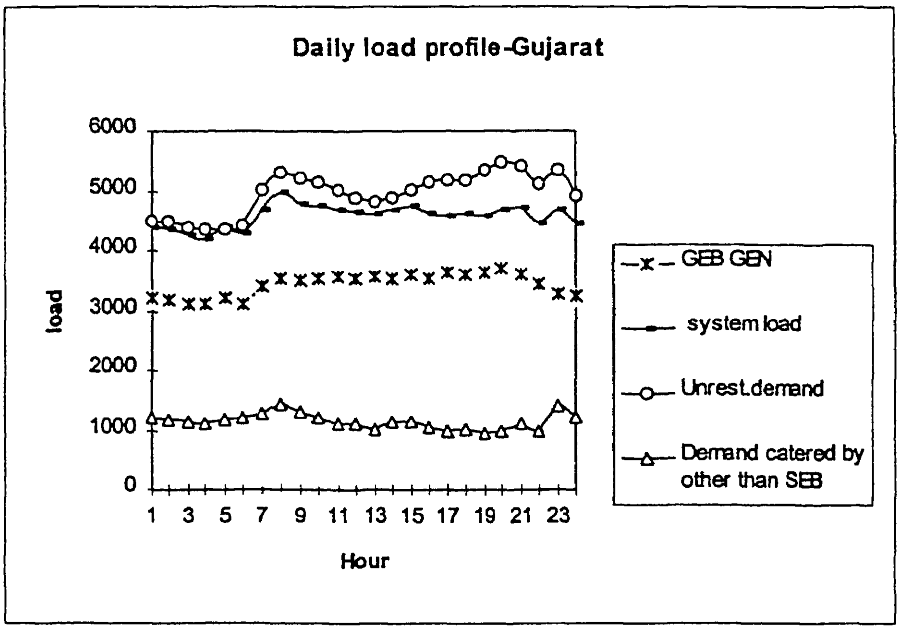
S. No.	Existing Technology	Proposed Technology	Sector	Simple Payback Years	Long Run Market Share	Economic Potential GWh saved
1.	Std. eff. motor	High eff. motor	Ind	1.05	78.00%	71.81
2.	Std. eff. Ind. pumps	High eff. Ind. pumps	Ind	0.19	99.00%	62.59
3.	Magnetic ballast	Electronic ballast	Ind	2.56	33.00%	36.35
4.	Ceiling fan	Efficient fan motor	Dom	2.81	50.00%	36.16
5.	TL Fluorescent	TLD Fluorescent	Ind	0.00	100.00%	35.05
	TOTAL POTENTIAL FOR ENERGY SAVINGS (GWh)					241.96

Besides saving on energy consumption, and thus on capacity requirements, GEB can also use its installed capacity more efficiently by flattening their system load curve. The existing system load factor for GEB is of the order of 0.80, which indicates a pretty flat load curve (Figure 1). Still, more than 100 MW of peaking capacity can be saved by shifting the industrial (both LT & HT) and agricultural loads to the off-peak hours (Table 2).

TABLE 2: Savings from Load Shifting

	Capacity savings due to reduction in peak demand (MW)	Annual energy savings (GWh) due to reduction in peak hour losses	Annual savings (million Rs)
LT - industrial sector	43.74	14.43	15.01
HT - industrial sector	40.41	13.33	13.86
Agricultural sector	19.60	1.76	1.83
TOTAL	103.75	29.52	30.70

FIGURE 1:



Cogeneration was also considered as an option for reducing the demand on GEB's system, and the potential in selected HT industries was estimated based on the response to questionnaires sent out to the HT industries by TERI. The details are tabulated in Table 3, and it has been estimated the seventeen industries listed can together generate 225 to 318 MW of power through cogeneration, of which 184 to 276 MW can be exported to the GEB grid.

Finally, the barriers to the implementation of the above options are identified, and methods recommended to overcome the same. In brief, the barriers are:

1. **Lack of information:** Usually it is seen that consumers have very little knowledge or information on energy efficient equipment and appliances available in the market. In the case of domestic appliances and lighting equipment, even the shopkeepers are largely ignorant about the energy consumption characteristics of the equipment sold by them.

2. **Consumer apathy:** Customers, especially in the domestic, commercial, and agricultural sector, have little knowledge of the efficiency of most appliances they buy and their impact on power consumption and energy costs.

Table: 3 Cogeneration Potential in Selected Industries

	GEB demand MW	Captive plant MW	Total demand	MAXIMUM Cogen potential (MW)	MINIMUM Cogen potential (MW)	MAXIMUM EXPORT TO GEB (MW)	MINIMUM EXPORT TO GEB (MW)
Core Healthcare Limited	17.00	5.00	22.00	22.00	22.00	5.00	5.00
Gujarat Ambuja Cements Limited	34.00	12.60	46.60	8.14	8.14	0.00	0.00
Polychem Limited	1.10	0.95	1.10	1.25	1.25	0.15	0.15
Gujarat Steel Tubes	2.50	4.23	2.50	3.00	3.00	0.50	0.50
Valsad SKY Mandali Ltd.	0.26	4.00	4.26	25.62	15.80	25.36	15.54
Sri Ukai Pradesh Sahakari Khand Udyog Mandli Ltd.	0 44	3.00	3.44	25.62	15.80	25.19	15.37
Sri Madhi Vibhag Khand Udyog Sahakari Mandli Ltd.	0.30	7.00	7.30	51.25	31.61	50.95	31.31
Shree Chalthan Vibhag Khand Udyog Sahakari Mandli Ltd.	0.42	8.00	8.42	51.25	31.61	50.83	31.19
Shree Madhuva Pradesh Sahakari Khand Udyog Mandli Ltd.	0.49	6.00	6.49	35.87	22.12	35.38	21.63
Shree Sayan Vibhag Sahakari Khand Udyog Mandli Ltd.	0 44	8.00	8.44	51.25	31.61	50.81	31.17
Dcw Limited	0.70	3.45	4.15	10.82	10.82	10.12	10.12
Gujarat Heavy Chemicals Limited	1.50	9.00	10.50	22.38	22.38	20.88	20.88
Camphor & Allied Products Ltd	0.09	0.00	0.09	0.10	0.10	0.01	0.01
The Ahmedabad Kaiser-I-Hind Mills Company Limited	1.80	1.60	1.80	2.00	2.00	0.20	0.20
Glaxo India Limited	1.50	2.70	1.50	2.75	2.75	1.25	1.25
Anil Starch Products Ltd.	4.30	1.00	4.30	4.50	4.50	0.20	0.20
Rosemount Pharma India Ltd.	0.48	0.00	0.48	0.50	0.50	0.02	0.02
TOTAL	67.32	76.53	133.37	318.30	225.99	276.85	184.54

3. **Subsidised electricity prices:** Tariffs paid by the domestic and agricultural sectors do not reflect GEB's true cost of supplying power. Thus they have little incentive to consider buying energy efficient equipment.

4. **High personal discount rates:** Customers usually have a very high personal discount rate which translates into them requiring very short payback period on investments on energy efficient equipment. Most domestic and commercial customers may require payback of less than a year. Even large industrial customers usually restrict investments to equipment with payback of under 3 years. Few customers conduct life-cycle studies to make investment decisions.

5. **Insufficient capital:** Most energy-efficient equipment are priced higher than standard efficiency equipment. Customers generally lack the initial capital required to finance purchase of energy-efficient equipment.

6. **Availability of EETs:** Efficient equipment and appliances are not always readily available in all regions, even in urban environments. Industrial equipment may have to be custom ordered in order to work with specific pieces of existing machinery.

7. **Lack of faith in EETs:** Consumers have little faith in the claims of energy efficiency made by the manufacturers. They are unwilling to invest in a new technology unless the benefits are demonstrated to them and/or their peers are using the same.

8. **Reliability of equipment in local conditions:** Energy efficient equipment used in the developed countries may be especially sensitive to the quality of power supplied and may not tolerate large deviations in voltage and/or frequency.

There are a number of ways in which the barriers to energy efficiency discussed above can be addressed. The more important ones are:

- Information campaigns
- Energy audits

- Codes, standards and labelling
- Co-operation with other stake holders in a DSM program
- Innovative tariffs and financial incentives
- Training
- Demonstration projects
- Market transformation

The identified DSM options have to be marketed to the consumers and for this a suitable marketing and delivery program consisting of a public relations and communication campaign, a joint promotion campaign with the manufacturers and retailers of EETs, and devising of relevant codes and standards in association with the government has been suggested.

It has also been recommended that a Demand Side Management department be created at the General Manager level. The DSM group should be staffed by full-time staff. Initially it is recommended that divisions be set up in the following areas, recognising that the organisation of the group will evolve over time:

- Public Relations/Communications
- Market research, technical assessment, planning, program evaluation
- Program design and implementation
- Industrial sector
- Commercial sector
- Domestic sector
- Agricultural sector
- Sales

In conclusion, while tremendous potential for energy savings exists in Gujarat through installation of energy efficient technologies (EETs); load shifting in LT industrial, HT industrial and agricultural sectors; and through promotion of cogeneration, the savings are almost wholly dependent on GEB promoting these options through path breaking policies.

Introduction

The state of Gujarat is located on the northernmost portion of the western coast of India. The state is highly industrialised and amongst the most developed in the country.

In keeping with the state it serves, Gujarat Electricity Board (GEB) is one of the progressive state electricity boards (SEB) in the country. As on March 31, 1994, GEB supplied power to 56.71 lakh consumers, distributed through more than 23 thousand circuit kilometres of transmission-distribution lines. The salient features of GEB as on March 31, 1995 are given in Table 0.1. These are taken from the General Review (1994-95), Central Electricity Authority, except for the T&D loss figure, which has been taken from the Profile of Power Utilities & Non-utilities in India, Council of Power Utilities.

Table 0.1: Salient features of GEB

S. No.	Item	Quantity
1.	Installed capacity	4372.48 MW
2.	Energy generated	21987.12 GWh
3.	T & D losses	19.25%
4.	Total energy sales (to ultimate consumers)	19865 GWh
5.	Energy sold to:	
a)	Domestic	1945 GWh
b)	Commercial	541 GWh
c)	Industrial LT	2073 GWh
d)	Industrial HT	6192 GWh
e)	Agriculture	8462 GWh
f)	Others	652 GWh

Source: Central Electricity Authority and Council of Power Utilities

The electricity board generates much of its own electricity, but also purchases power from state and central government owned generating companies. Gujarat boasts a

huge amount of captive power generation capacity, owned by the HT industries, which accounts for about 20% of the total installed capacity in the state.

GEB has started on a program of implementing a computerised LT billing and accounting system, in order to enhance the level of service it provides its consumers.

The Gujarat Electricity Board is also actively promoting the use of non-conventional sources of energy and uses solar water heaters at many of its guest houses. GEB has also participated in the installation of solar powered street lights, wind farms and bio-mass based generation.

GEB had set up an Energy Conservation Cell in 1982, and the cell offers advisory services in the form of energy audits to the industrial consumers of the Board.

The state is facing a power shortage situation in 1996-97, and HT industries have been asked to either resort to a 5-day work week, or take a voluntary demand cut of 20% on their contacted demand. In the urban areas, load shedding for time periods of 30 minutes each is carried out by rotation in the morning (6:00 - 7:00 a.m.) and evening (8:00 - 10:00 p.m.). The agriculture sector gets three-phase supply for about 12 hours a day.

The traditional method to bridge this demand/supply gap would be to build new power plants and thus augment generating capacity. Two major drawbacks of this approach are the necessity of investing large financial resources, and the degradation of the environment.

Demand Side Management (DSM) is an alternative approach which has gained favour in recent years. This approach looks at augmenting capacity by way of saving on energy use by the existing consumers. Every MW which is saved from the existing load, is free to be delivered to new customers.

It is felt that the Demand Side Management (DSM) plan outlined in the report, will be of help in mitigating the current situation of power shortage, and will also enable the

state government in general, and the power sector organisations in particular, to utilise their financial resources in the most cost effective manner.

The chapters which follow are arranged in the same order as the scope of the study, which is as given below.

1. **Demand and load curve analysis** - The load profile of the major consumer categories is to be evaluated through data collected from primary surveys and review of data available with GEB.
2. **Identification and screening of energy efficient technologies for various end-uses** - Initially a literature review is to be carried out to identify the energy efficient technologies (EETs) suitable for implementation in Gujarat. The EETs are then to be subjected to an initial evaluation based on cost criteria, and then to a detailed screening which includes both quantitative and qualitative criterion. Based on the screening, a list of ten most attractive options is to be developed.
3. **Develop technical, economic and market potential of EETs** - The technical, economic and market potentials for the EETs identified through the literature survey are to be estimated. The ten most attractive EETs are to be identified based on this analysis.
4. **Develop innovative electricity pricing options for DSM** - Innovative tariff options for potential application by GEB are to be identified after reviewing the various options used in other developed countries.
5. **Assess the potential role of cogeneration as an option for demand management** - The potential of cogeneration in the different industrial categories is to be assessed through a survey of the industries in the state. The various technical, economic and institutional issues that are presently constraining increased use of cogeneration are also to be addressed.
6. **DSM program design** - A detailed DSM program for GEB is to be designed. Specific programs for various end-uses, based on the screening carried out in earlier tasks are to be recommended for various end-uses. Barriers and constraints to the implementation of the DSM program are to be identified and measures suggested to overcome the same.

CHAPTER 1

CHAPTER 1
Demand and load curve analysis

1.1 Background

Gujarat Electricity Board (GEB) is responsible for supplying power to the different categories of consumers of the state of Gujarat, except for the command areas of the Ahmedabad Electricity Company and the Surat Electric Company. In addition to its own generation GEB relies on exchanges of power with the National Thermal Power Corporation (NTPC), Nuclear Power Corporation (NPC), Gujarat Industries Power Company Limited (GIPCL), and other neighbouring state electricity boards to meet its electricity demand. The load dispatch centre at Jambua gathers data on power generation and exchange of power with other utilities. The load dispatch centre also anticipates hourly system demand and dispatches power accordingly. Primary, secondary and tertiary substations at different voltage levels keep records of power flows through feeders. Electricity consumption by customers in the residential, commercial, industrial, agriculture, and other sectors is determined based on billing data.

1.2 Introduction

Demand and load curve analysis is the most important subtask of this DSM study being conducted for GEB. In this subtask of the study the supply of power to customers was analysed to determine the loads served by GEB. Data on power flow from the load dispatch centre was analysed to obtain system level hourly load shapes. The system level hourly load data was then disaggregated by consumption sector to obtain sector level load shapes. Load shapes for specific end uses in different sectors were also developed. The methodology adopted for this study, the data collection effort, data analysis and the results of these analyses are described here in this chapter.

1.3 Objectives of load shape analysis

Load shape analysis is the basic building block for analysing impact of strategies to change demand patterns or effect energy conservation, and impact of tariff revision.

System level hourly load shapes exhibit the hourly variations in electricity demand and display the system peak and off peak periods. Coupled with costs and reliable

forecasts, system load shapes can be used to determine appropriate load shape objectives such as peak clipping, valley filling strategic load growth which can be use to optimally plan new capacity requirements.

Sector load shapes provide additional information on loads imposed by different categories of customers and their contribution to the system load shape. This information is pertinent to developing suitable tariff structures for equitable revenue realisation, or deciding on incentives/penalties schemes which may help meet load shape objectives. Sector level shapes are also an indispensable tool in designing DSM programs which target end uses in the appropriate sector to cost effectively meet load shape objectives.

1.4 Methodology

Two approaches to conduct sector level load survey analysis were selected- feeder data analysis and customer load data analysis. Feeder level data was used to develop load shapes for the agricultural and HT-industrial sectors, while data from customer load surveys were used to develop load shapes for the residential, commercial and LT industrial sectors. A metering approach to data collection was not considered feasible in view of the available resources and was beyond the scope of this study.

The collected representative sample hourly load data from the feeders and customers surveys and hourly load data were scaled to reflect the total consumption within each sector. Sector level load shapes were developed using these data. The details of the specific methodology adopted for each sector and the assumptions made in the analyses are described elsewhere in this chapter.

1.5 Data analysis

System load shape analysis was done at two levels- State demand and GEB load. System hourly load shape for the state was determined directly form the data collected form GEB records. The following observations can be made from a visual analysis of the figure 1.1 below. In absence of any supply constraint (unrestricted demand), the system would have peak demand at around 8 am and 8 p.m. in the evening. However, in the present situation the system load profile is virtually flat as there is not enough capacity to meet peak time demand and to a certain extent even normal demand.

Clearly there is limited scope for demand management by shifting loads. The overall system load shapes (both restricted and unrestricted) shown in figure 1.1 are provided by the State Load Despatch Centre (SLDC) of GEB.

This is further borne out by the Table 1.1 below which gives the system load factor for maximum demand days for last three years. Increasing load factors indicate the supply constraint may be becoming more serious over the years.

FIGURE 1.1:

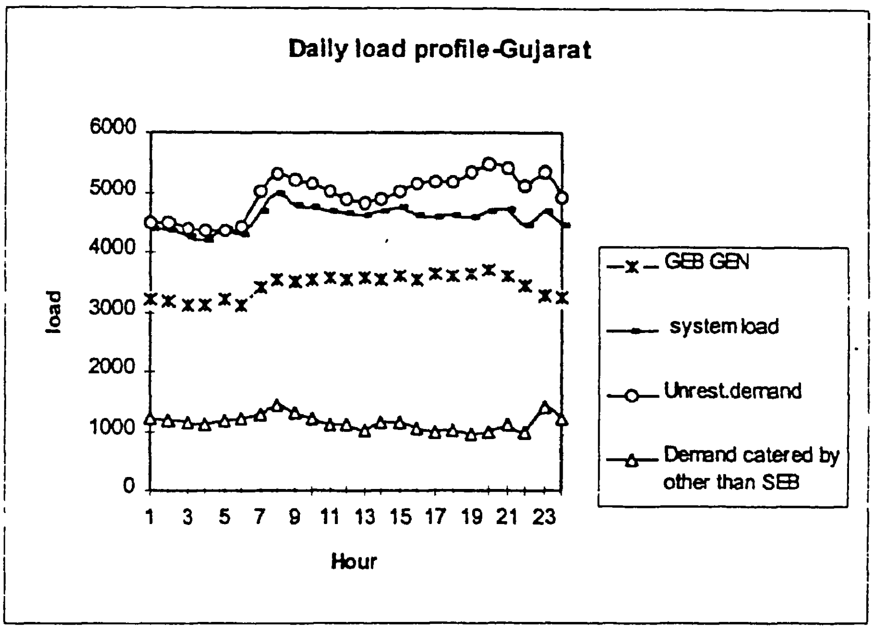


TABLE 1.1: Peak day load factor

Year	Average load (MW)	Maximum load (MW)	Load factor
1992-93	3658	4280	0.85
1993-94	4210	4580	0.92
1994-95	4582	4981	0.92

1.6 Sector level load shapes

1.6.1 Description of sectors

The industrial and agriculture sectors are the largest consumers of power in the state, together accounting for nearly 85% of the total sales. Domestic and commercial

sectors account for 10% and 3% respectively while the remaining sectors account for the rest. Each of these sectors was analysed separately to determine their individual contribution to the system load shape. It is important to remember that the individual load shapes and their peaks may not coincide with system peak.

1.6.2 Methodology for sectoral load shapes

After assessing data availability, approaches to conduct sector level load survey analysis were decided upon- feeder level analysis and customer load data analysis. Feeder data were used to develop load shape for the agricultural and HT industrial sectors and data from customer load surveys were used to develop load shapes for the domestic, commercial and LT. industrial sectors.

1.6.3 Feeder data analysis

The load shapes for HT industry and agriculture sector was developed on the basis of feeder level data. Most of the HT industries are getting power through dedicated feeders. About 14 such feeders supplying power exclusively to a wide variety of industries were identified in consultation with the GEB staff. In all data on current over a 24 hour period was collected for forty two days of the year. A similar approach was adopted for developing load shape for the agriculture sector where the load is mainly on account of irrigation pumpsets.

1.6.4 Customer load survey data analysis

Separate dedicated feeders are not normally used to serve loads in the commercial, residential and LT. industrial sectors. GEB has little information on the energy use pattern in these sectors rendering impossible the development of load shapes without making gross assumptions about appliance load and usage pattern. The customers in these sectors had to be surveyed to generate this primary data. A metering approach to load survey was deemed impractical in view of the high cost of the meters and the long lead times involved in procuring and installing meters. A customer survey was thus considered the best approach to developing data.

After consultation with the GEB staff , three areas within Baroda district was identified for administering questionnaires to collect information on the pattern of energy consumption and other appliance related characteristics. The consumers were

randomly picked up from the master list of consumers located in the above mentioned areas after grouping them in five consumer classes. The sector wise discussion of the results follows.

1.7 Domestic sector

1.7.1 Description of Sector

The domestic sector with over 5 million customers represents a little over 70% of GEB's customers but account for 10% of the total energy consumption. The sector contributes less than 10% to GEB's total revenue.

1.7.2 Results of the data analysis

The customer load survey data was analysed to determine sectoral load shape. The figure 1.2 shows the average daily load shape of domestic consumers ignoring seasonal variations. The load profile obtained from the sample data was scaled up to reflect the energy consumption of this sector. The load shape has three distinct peaks the most prominent one occurring around eight in the evening. The other prominent periods of high demand are around 7 a.m. and 1 p.m.

FIGURE 1.2

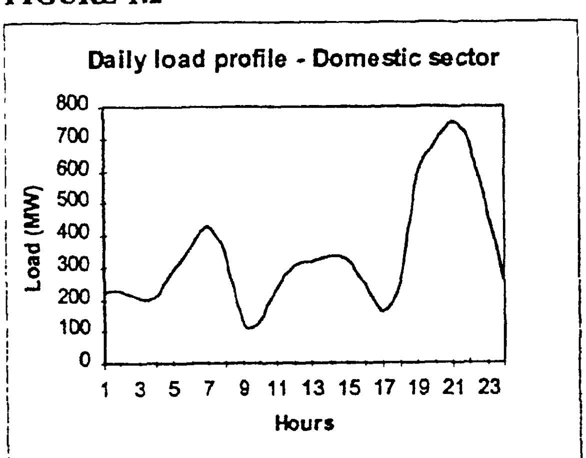


Table 1.2 shows the importance of various devices in daily energy consumption in different time slots.

TABLE 1.2: Percentage share of each device in daily energy consumption

	S1	S2	S3	S4	Total
BULB 40 W	0%	0%	0%	3%	3%
BULB 60 W	0%	0%	0%	2%	2%
TUBE 4F N	0%	1%	0%	6%	7%
TUBE 4F T	0%	0%	0%	0%	1%
FANS	6%	9%	6%	12%	34%
A. C.	2%	0%	1%	4%	7%
FRIDGE	4%	9%	8%	5%	27%
BOOSTER	0%	3%	0%	0%	3%
GEYSER	0%	4%	0%	0%	4%
TV	0%	1%	2%	11%	13%
Total	13%	27%	17%	43%	100%

Note: *(S1=23.00 - 05.00 hours), (S2=05.00 - 09.00 hours), (S3=09.00 - 17.00 hours), (S4=17.00 23.00 hours)*

While lighting load accounts for about 13% of total energy consumption practically all of this is concentrated in the evening hours. Slightly less than half of the energy is consumed in the evening hours. Lighting, fans and television account for slightly over three fourths of the consumption occurring during this time.

Table 1.3 gives the percentage share of each device in each time slot during the day.

TABLE 1.3: Percentage share of each device in each time slot

Device	S1	S2	S3	S4
BULB 40 W	1%	1%	1%	6%
BULB 60 W	1%	0%	0%	4%
TUBE 4F N	2%	2%	1%	13%
TUBE 4F T	0%	0%	0%	1%
FANS	46%	34%	37%	29%
A.C.	18%	1%	4%	9%
FRIDGE	32%	34%	47%	12%
BOOSTER	0%	11%	0%	0%
GEYSER	0%	13%	0%	0%
TV	0%	3%	9%	25%
Slot wise totals	100%	100%	100%	100%

Table 1.4 gives some idea of load profile of different appliances. Fan, television and lighting loads display sharp peak around the evening hours, ACs to somewhat lesser extent. Because the system unconstrained peak occurs in the evening and also because these devices account for significant share in daily energy consumption. the nature of their particular load profile naturally assumes importance from the energy conservation perspective.

TABLE 1.4: Slot wise energy use variation for each device(%)

Device	S1	S2	S3	S4
BULB 40 W	2%	7%	6%	85%
BULB 60 W	9%	3%	0%	89%
TUBE 4F N	3%	9%	2%	86%
TUBE 4F T	0%	4%	10%	86%
FANS	18%	27%	18%	37%
A.C.	33%	3%	10%	53%
FRIDGE	16%	35%	29%	19%
BOOSTER	0%	100%	0%	0%
GEYSER	0%	100%	0%	0%
TV	0%	6%	11%	82%

The morning peak and the evening peak of domestic sector is somewhat coinciding with the system peak (8 a.m. and 7:30 p.m.). During the morning hours, 27% (S2) of the total energy is consumed, out of which the major components are fans (9%), refrigerators (9%) and geysers (4%). Most of these loads are time specific loads and cannot be shifted to other place on time axis. During the evening hours, lighting load constitutes 11%, fans 12% and TV 11%. These types of loads may not be shifted to some other time. Hence the possible potential of shifting the peak domestic loads to off-peak time appears to be negligible. These peaks can be reduced by various energy efficiency measures.

DSM measures are discussed in another part of this report.

1.8 Commercial sector

1.8.1 Description of the sector

The commercial sector represents about 10% of GEB customers and accounts for only 3% of GEB sales. The results of the survey data are reported below.

1.8.2 Results of Data analysis

The customer load survey was analysed to determine sectoral load shape and to estimate the contribution of different appliances to total electricity consumption. The figure 1.3 shows the commercial sector load shape for a typical day. The load shape exhibits peak starting about 9 am coinciding with opening of commercial establishments. The load continues to rise and peaks about 12 noon before dropping slightly in the afternoon. The load then picks up about 1 p.m. and increases resulting in evening peak around 6 p.m. and then starts dropping. The larger evening peak is likely due to increased lighting load. However compared to domestic sector the commercial sector load contributes little to system load shape.

Table 1.5 shows the percentage contribution by various appliances to electricity consumption.

FIGURE 1.3

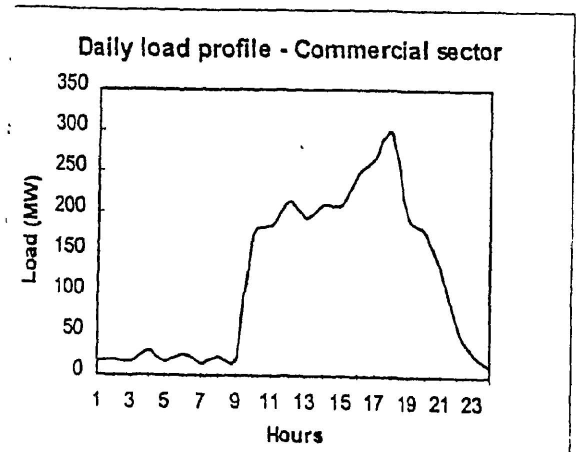


TABLE 1.5: Percentage share of each device in daily energy consumption

	S1	S2	S3	S4	S5	S6	S7	Total
BULB 60	0%	0%	0%	1%	1%	2%	0%	4%
BULB 100	0%	0%	0%	0%	0%	1%	0%	1%
MERCURY	0%	0%	0%	0%	2%	2%	0%	4%
TUBE 4F N	0%	0%	0%	2%	2%	3%	0%	8%
TUBE 4F T	0%	0%	0%	0%	1%	1%	0%	2%
A.C.	0%	0%	0%	10%	18%	4%	1%	33%
FANS	1%	0%	1%	10%	12%	5%	1%	30%
TV	0%	0%	0%	0%	0%	0%	0%	1%
FRIDGE	1%	0%	0%	1%	1%	0%	0%	4%
DEEP FR.	2%	1%	1%	2%	2%	1%	1%	10%
COMPUTER	0%	0%	0%	1%	1%	0%	0%	2%
PRINTER	0%	0%	0%	0%	1%	0%	0%	1%

Note (S1=12.00 - 05.00 hours), (S2=05.00 - 07.00 hours), (S3=07.00 - 09.00 hours), (S4=09.00 - 13.00 hours), (S5=13.00 - 18.00 hours), (S6=18.00 - 21.00 hours), (S7=21.00 - 00.00 hours)

TABLE 1.6: Percentage share of each device in each time slot

Device	S1	S2	S3	S4	S5	S6	S7
BULB 60W	4%	2%	3%	2%	2%	10%	8%
BULB 100W	0%	0%	1%	0%	1%	5%	3%
MERCURY Bulb	0%	0%	0%	0%	5%	9%	0%
TUBE 4F N	3%	4%	6%	6%	5%	17%	8%
TUBE 4F T	0%	0%	1%	1%	1%	3%	0%
A.C.	0%	0%	0%	38%	43%	21%	17%
FANS	16%	17%	53%	38%	29%	25%	15%
TV	0%	0%	0%	0%	0%	2%	4%
FRIDGE	21%	19%	10%	3%	3%	2%	6%
DEEP FR.	57%	58%	26%	7%	6%	7%	39%
COMPUTER	0%	0%	0%	2%	3%	0%	0%
PRINTER	0%	0%	0%	2%	2%	0%	0%
	100%	100%	100%	100%	100%	100%	100%

From tables 1.6 and 1.7 it would seem that evening peak in the commercial sector is on account of ACs, fan and lighting load.

TABLE 1.7: Slot wise energy use variation for each device(%)

	S1	S2	S3	S4	S5	S6	S7	Total
BULB 60	3%	1%	2%	14%	22%	52%	7%	100%
BULB 100	0%	0%	3%	0%	17%	72%	8%	100%
MERCURY	0%	0%	0%	0%	54%	46%	0%	100%
TUBE 4F N	1%	1%	2%	20%	29%	44%	4%	100%
TUBE 4F T	0%	0%	2%	21%	35%	42%	1%	100%
A.C.	0%	0%	0%	31%	54%	13%	2%	100%
FANS	2%	1%	5%	34%	40%	17%	2%	100%
TV	0%	0%	0%	0%	24%	53%	24%	100%
FRIDGE	17%	6%	7%	24%	31%	10%	6%	100%
DEEP FR.	17%	7%	7%	18%	23%	14%	14%	100%
COMPUTER	0%	0%	0%	36%	64%	0%	0%	100%
PRINTER	0%	0%	0%	37%	63%	0%	0%	100%

As table 1.5 indicates these end uses also account for major share in total energy consumption of the sector. Interestingly, the individual load shapes of these devices peaks around late afternoon and early evening hours. For all these reasons DSM programs should target these end uses for improvement in energy efficiency. Since majority of the loads during evening hours (S5 & S6) are commercial lights, fans and A.Cs, shifting of these loads is not possible. However, energy efficiency measures like installations of CFLs in place of incandescent lamps, use of A.Cs with higher EER will reduce the evening peak to some extent.

1.9 Industrial sector

1.9.1 Description of the sector

The industrial sector represents over 4% of GEB customers but accounts for over 40% of GEB electricity sales. The industrial sector can be broadly categorised as LT (low tension) industry and HT industry. Industries having demand of less than 100 kVA are provided with LT connections. These industries receiving power at relatively lower voltage and are not fed by dedicated feeders. HT industries (High tension) usually have connected load over 100 kVA and are commonly fed by dedicated express feeders. The two categories were analysed separately.

1.9.2 LT industrial sector

The LT industry represents over 98% of all industrial consumers but accounts for only about 25% of total industry sales.

1.9.3 Results of the data analysis

The customer load survey data was analysed to determine sectoral load shape and estimate the contribution of different appliances to total industrial sector electricity consumption within each segment. The figure 1.4 shows the annual LT industrial sector load shape. The load peaks around 9 am and remains constant till 11 am. This coincides with the start of the first shift. Since most of the units in LT sector being usually one or two shift operations, the evening load is not very high and consequently the morning peak is higher than the afternoon peak which occurs around 4 p.m.

Analysis of the Load shapes for examining the possibility of shifting the load from peak to off-peak is carried out. Daily load curve of the GEB power system for a typical day as furnished by GEB is shown in figure 1.5. The corresponding load curve for the LT-industrial sub-sector showing hourly load variations on the same day is shown in figure 1.6. The GEB system load shape has a morning peak between 8:00 and 9:00 a.m. in the morning whereas the LT-industrial peak occurs during 8:00 a.m. and 11:00 a.m. in the morning. Hence the contribution of the LT-industrial loads to the system peak is very less. However an attempt has been made to shift some of the LT-industrial load to the off-peak and its impact on the system load shape. Figure 1.5 shows the original system load shape and the modified load shape after reshaping the industrial load demand. The modified loading pattern of the LT-industrial sector would result in reduction of peak loads from 4981 MW to 4875 MW and peak hours losses from 1040.58 MW to 996.84 MW. This reduction in peak hour losses (43.74 MW) for 1 hour will reduce the peak hour energy losses by 43.74 MWh. The annual monetary gain accrue to GEB due to reduction in peak hour losses are calculated in Annexure 1.2. These modifications in the load shape of LT industrial sector is proposed through tariff incentives

During our discussions with the GEB officials it was revealed that LT industries are least responsive to shifting the load from morning to night hours. Therefore shifting of

sectoral loads has been sequenced in such a manner (LT industrial sector followed by HT industries and then agricultural sector) that a suitable working time during day hours can be provided to the LT consumers. Agricultural sector is given least priority because the labour requirement during electricity supply hours is the least. Therefore system load shape smoothened by changing the LT industrial load shape is further flattened by modifying the sectoral load shapes of HT industrial and then agricultural sectors respectively.

Table 1.8 shows the percentage contribution of various appliances to total consumption. The motors account for over three fourth of total energy consumption. The other category comprising largely of end uses like furnace, storage water heaters account for the other major share in electricity consumption.

Table 1.9 indicates the importance of various devices in each time slot. Given the importance of motors in overall electricity consumption it is hardly surprising that peak time consumption is also on account of motor related loads.

This is to be seen in conjunction with the fact that the peak of the motor load profile (See table 1.10) occurs around the same time as sector's peak demand.

The load shift in the LT industrial sector has been restricted to between 7:00 a.m. and 9:00 a.m. as this period coincides with the system morning peak. Also, the sectoral peak occurs during this time due to the heavy startup loads from all the LT industries. It is suggested that the opening times of the LT industries in different localities be staggered in the morning to avoid simultaneous loading of the GEB system.

FIGURE: 1.4

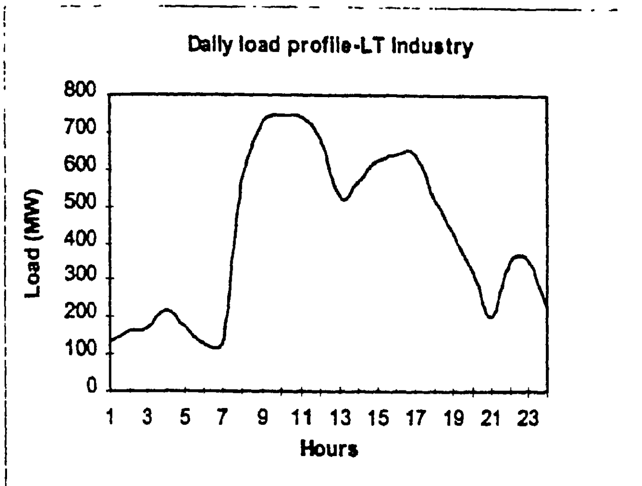


TABLE 1.8: Percentage share of each device in daily energy consumption

	S1	S2	S3	S4	S5	S6	S7	Total
BULB 100	0%	0%	0%	0%	0%	0%	0%	1%
MERCURY	0%	0%	0%	0%	0%	0%	0%	1%
TUBE 4F N	0%	0%	0%	0%	0%	0%	0%	1%
TUBE 4F T	0%	0%	0%	0%	0%	0%	0%	0%
A.C.	0%	0%	0%	1%	1%	0%	0%	3%
FANS	0%	0%	0%	1%	1%	0%	0%	2%
FRIDGE	0%	0%	0%	0%	0%	0%	0%	0%
COMPUTER	0%	0%	0%	0%	0%	0%	0%	0%
PRINTER	0%	0%	0%	0%	0%	0%	0%	0%
MOTORS	5%	1%	11%	21%	24%	7%	7%	76%
OTHERS	2%	1%	2%	4%	4%	1%	1%	16%
TOTAL	8%	2%	13%	27%	30%	10%	10%	100%

Note: (S1=12 00 - 05 00 hours), (S2=05.00 - 07.00 hours), (S3=07.00 - 09.00 hours), (S4=09.00 - 13 00 hours), (S5=13.00 - 18 00 hours), (S6=18.00 - 21.00 hours), (S7=21.00 - 00.00 hours)

TABLE 1.9: Percentage share of each device in each time slot

	S1	S2	S3	S4	S5	S6	S7
BULB 100	2%	1%	0%	0%	0%	2%	1%
MERCURY	6%	4%	0%	0%	0%	3%	4%
TUBE 4F N	2%	2%	0%	1%	1%	2%	1%
TUBE 4F T	0%	0%	0%	0%	0%	0%	0%
A.C.	6%	9%	2%	3%	3%	3%	3%
FANS	1%	1%	1%	2%	2%	2%	1%
FRIDGE	0%	1%	0%	0%	0%	0%	0%
COMPUTER	0%	0%	0%	0%	0%	0%	0%
PRINTER	0%	0%	0%	0%	0%	0%	0%
MOTORS	58%	48%	80%	78%	78%	76%	77%
OTHERS	25%	35%	16%	15%	15%	12%	12%
TOTAL	100%	100%	100%	100%	100%	100%	100%

TABLE 1.10: Slot wise energy use variation for each device(%)

	S1	S2	S3	S4	S5	S6	S7	
BULB 100	21%	2%	3%	11%	15%	34%	14%	100%
MERCURY	41%	8%	0%	0%	0%	20%	31%	100%
TUBE 4F N	17%	4%	6%	18%	20%	22%	13%	100%
TUBE 4F T	8%	0%	10%	27%	33%	17%	5%	100%
A.C.	15%	6%	9%	26%	27%	9%	9%	100%
FANS	4%	1%	8%	35%	38%	11%	3%	100%
FRIDGE	13%	5%	7%	25%	32%	9%	9%	100%
COMPUTER	0%	0%	0%	43%	52%	4%	0%	100%
PRINTER	0%	0%	0%	58%	42%	0%	0%	100%
MOTORS	6%	1%	14%	28%	31%	10%	10%	100%
OTHERS	12%	5%	13%	26%	29%	7%	7%	100%

1.9.4 HT- industrial sector

The HT industry while accounting for around 1% of all industrial consumers consumes almost 75% of industry sales. Feeder data was collected to analyse usage pattern of HT industrial sector. The HT industrial sector load shapes were analysed using data from express feeders. Hourly data on current was collected from the logsheets for 14 industrial feeders. In all data for 42 observations were collected.

Figure 1.5: System Load Shapes - LT Industry

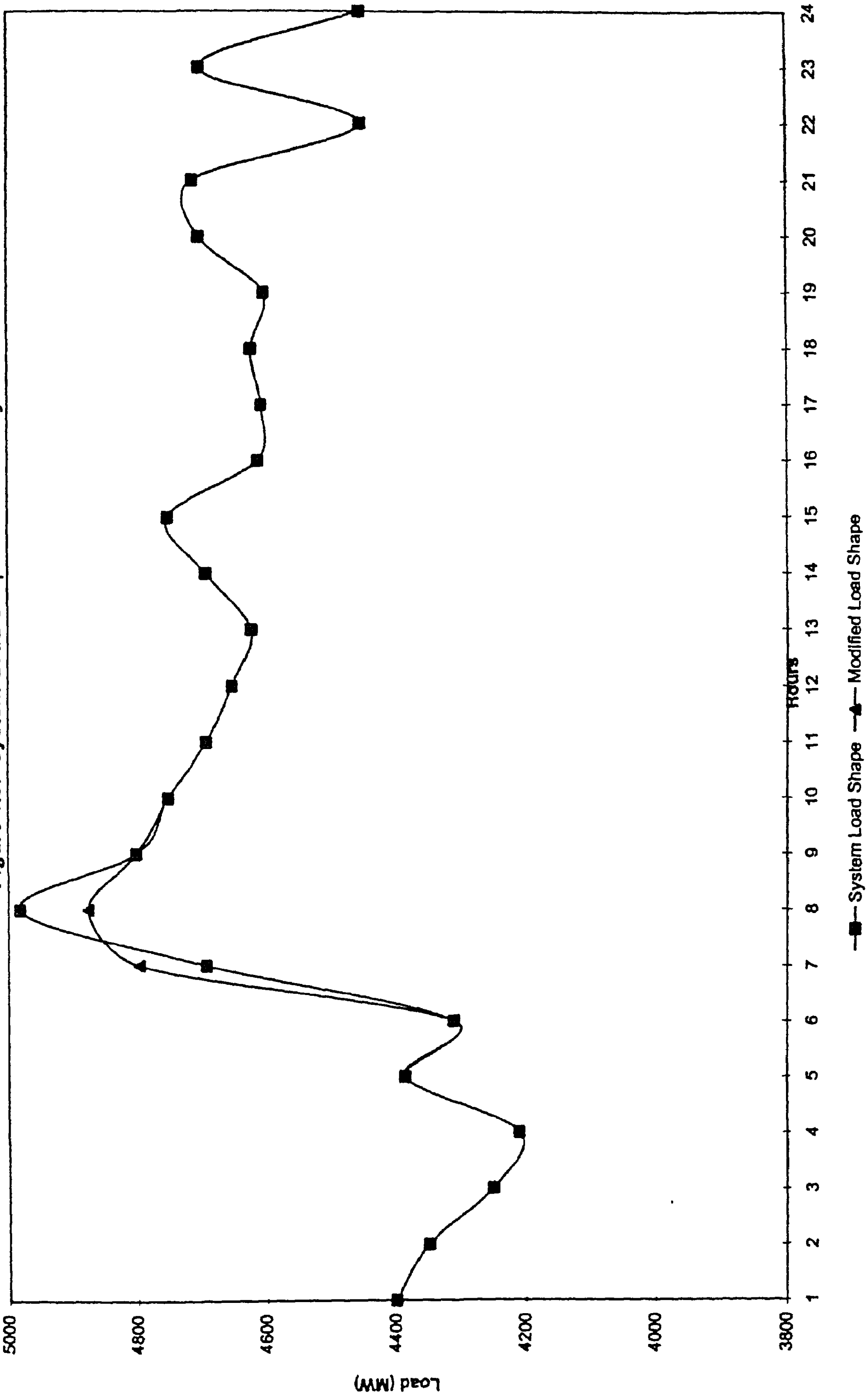
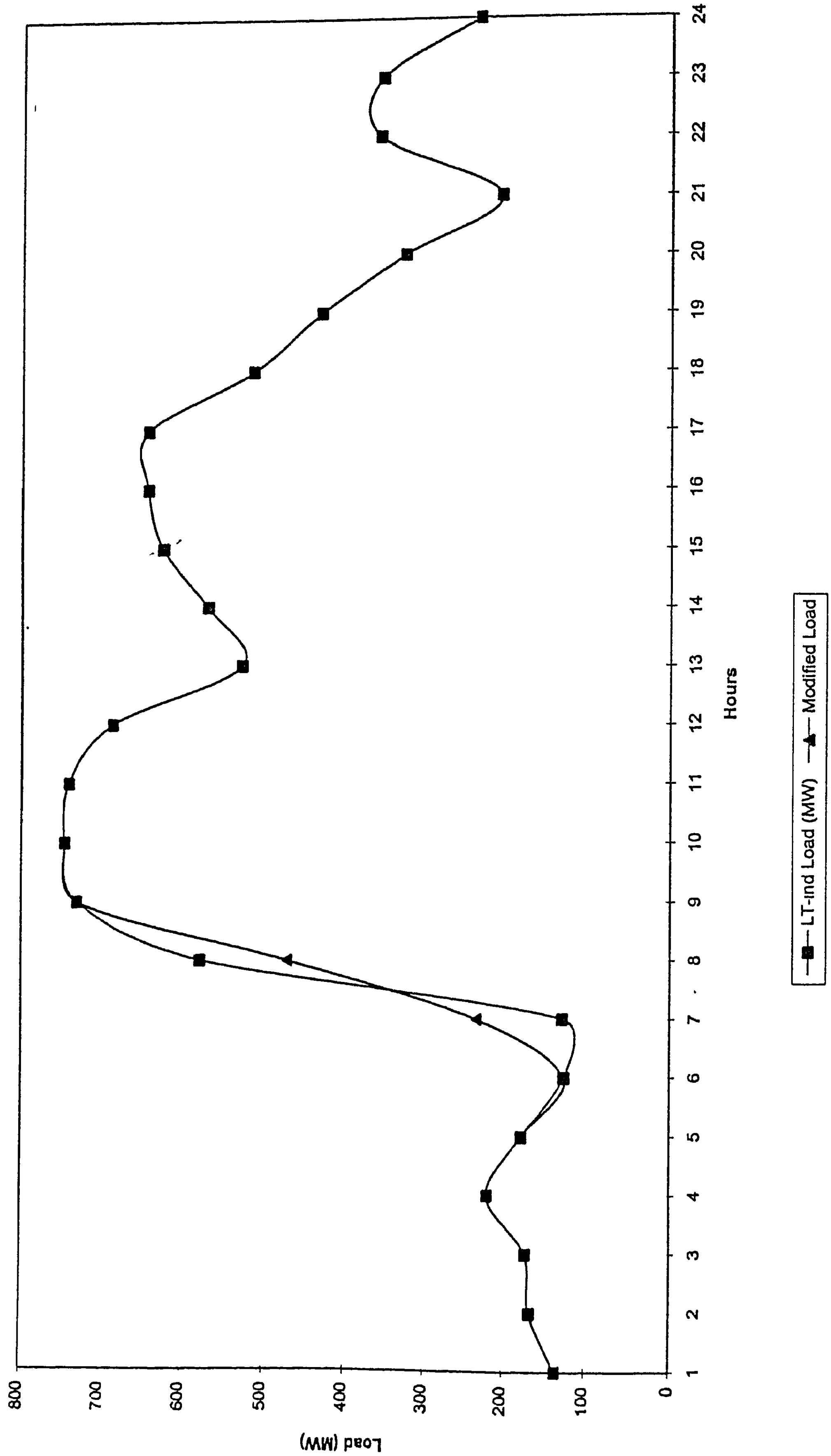


Figure 1.6: Daily load profile-LT Industry

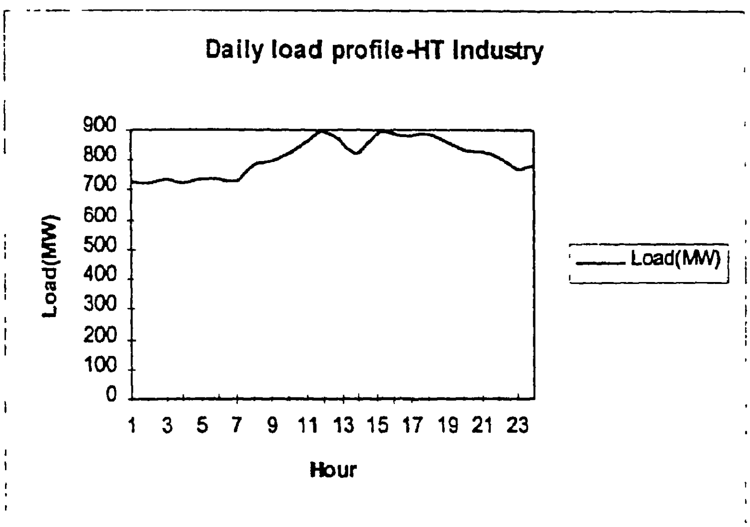


Sectoral load shape was developed for a typical day of the year. Details of the power cuts on the HT industries from 1987 to 1995 is given in table 1.11.

1.9.5 Results from analysis

The average load shape is shown below in figure 1.7. It is clear that the load shape does not vary much over the hours of the day. Though the load increases during daytime, the increase itself is marginal.

FIGURE 1.7



Analysis of the Load shapes for examining the possibility of shifting the load from peak to off-peak is carried out. These modifications in the load shape is proposed through tariff incentives. *The modified system load shape from the LT-industrial sector would be used here as the base system load shape to evaluate the impact of shifting the HT industrial daily demand to the system load shape.* The system load shape and the corresponding improved system load shape for GEB is shown in figure 1.8. The modified loading pattern of the HT-industrial sector (shown in figure 1.9) would result in reduction of peak loads from 4875 MW to 4775 MW and peak hours losses from 996.84 MW to 956.43 MW. This reduction in peak hour losses (40.41 MW) for 1 hour will reduce the peak hour energy losses by 40.41 MWh. The annual monetary gain accrue to GEB due to reduction in peak hour losses are calculated in Annexure 1.3. It is recommended that Time-of-Use tariffs or load rostering be used to shift the load in HT industries between 6:00 a.m. and 10:00 a.m.

Table 1.11: Power cuts on HT industries

Month	1987-88 Date %	1988-89 Date %	1989-90 Date %	1990-91 Date %	1991-92 Date %	1992-93 Date %	1993-94 Date %	1994-95 Date %
April	1to29 15% 30 40%	1to23 15% 24to30 25%	1to30 Nil	1to30 Nil	1to30 Nil	1to30 Nil	1to30 Nil	1to30 Nil
May	1to23 15% 24to31 Nil	1to6 25% 7to9 15% 10 50% 11to13 70% CP/ 100 NCP 14 25% 15to16 15% 17to31 Nil	1to31 Nil	1to31 Nil	2to4 25% 5to6 30% 7to14 35% 15to31 20%	1to31 Nil	1to31 Nil	1to31 Nil
June	1to19 Nil 20 25% 21to27 50% 28to29 25% 30 Nil	1to30 Nil	1to30 Nil	1to30 Nil	1to11 20% 12to30 Nil	1to30 Nil	1to30 Nil	1to30 Nil
July	1to30 Nil 31 25%	1to31 Nil	1to31 Nil	1to31 Nil	1to31 Nil	1to31 Nil	1to31 Nil	1to31 Nil
August	1to20 50% 21to26 40% 27to31 25%	1to31 Nil	1to31 Nil	1to4 40% 5to18 10% 19to31 Nil	1to30 Nil	1to31 Nil	1to31 Nil	1to31 Nil
September	1to8 25% 9 100% 10to11 25% 12 25% Ist 50%2&3 13 50% 14to30 40% &26to30 - Addl H'day NCP/HT/LT	1to30 Nil	1to30 Nil	1to8 Nil 9to21 40% 22to28 20% 29to30 10%	1to18 Nil 19to22 25% 23to30 40%	1to30 Nil	1to3 Nil 4to20 20% 21to30 Nil	1to30 Nil

Table 1.11: Power cuts on HT industries (contd.)

Month	1987-88 Date %	1988-89 Date %	1989-90 Date %	1990-91 Date %	1991-92 Date %	1992-93 Date %	1993-94 Date %	1994-95 Date %
October	1to19 40% & Addl h'day NCP/HT/LT 20to31 25% & Addl h'day NCP/HT/LT	1to31 Nil	1to31 Nil	1to4 10%	1to2& 6to18 40% 5to7& 12to14 100% NCP	1to31 Nil	1to31 Nil	1to6 Nil 7to22 Addl Stagg day for LT Ind 7to28 -do- for HT 7to31 LT Ind not to draw power bet. 18to22 hours
November	1to30 25%	1to30 Nil	1to17 Nil 18to30 20%	1to30 Nil	1to4 20% 5to28 Nil 29to30 50%	1to30 Nil	1to30 Nil	1to30 Nil
December	1to26 25% 27to31 Nil	1to8 Nil 9to16 15%	1to11 15% 16to28 25% 29to31 15%	1to31 Nil	1to12 50% 13to31 20%	1to31 Nil	1to31 Nil	1to31 Nil
January	1to4 Nil 5 25% 6to7 50% 8to13 50% HT CP 100% HT NCP 14to31 25% 14to31 25%	1to31 Nil	1to15 15%	1to24 Nil 23to25 40% 28to31 40%	1to31 20%	1to31 Nil	1to31 Nil	1to31 Nil
February	14to31 25%	1to28 Nil	1to28 Nil	1to4 40% 5to28 Nil	1to2 20% 3to29 Nil	1to28 Nil	1to28 Nil	1to28 Nil
March	1to31 15%	1to31 Nil	1to31 Nil	1to18 Nil 19 40% 20to22 15/25%	1to31 Nil	1to31 Nil	1to31 Nil	1to31 Nil

Source: Generation Department, Information & Achievments, Gujarat Electricity Board, 1995-96.

Figure 1.8: System Load Shapes-HT industry

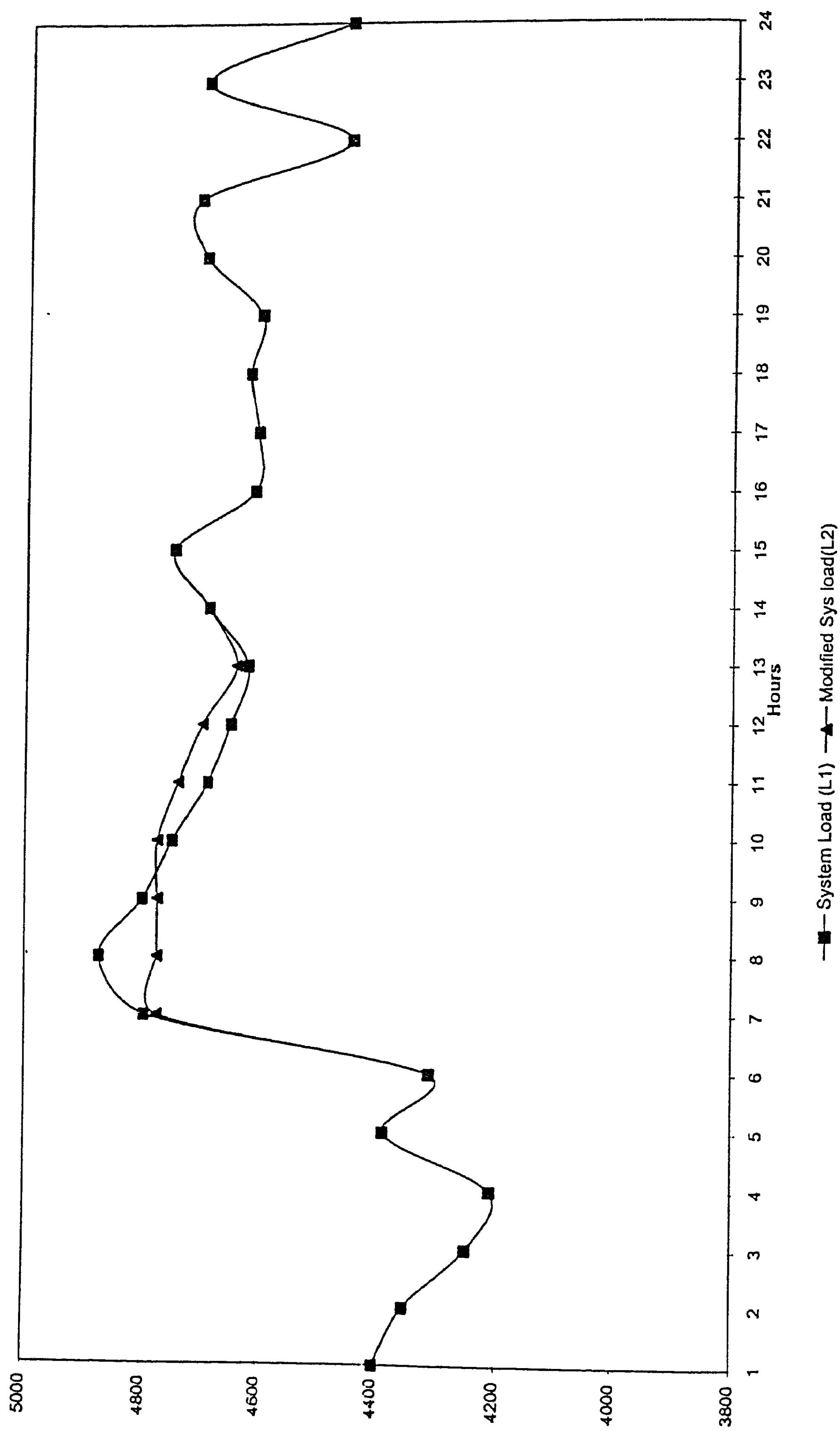
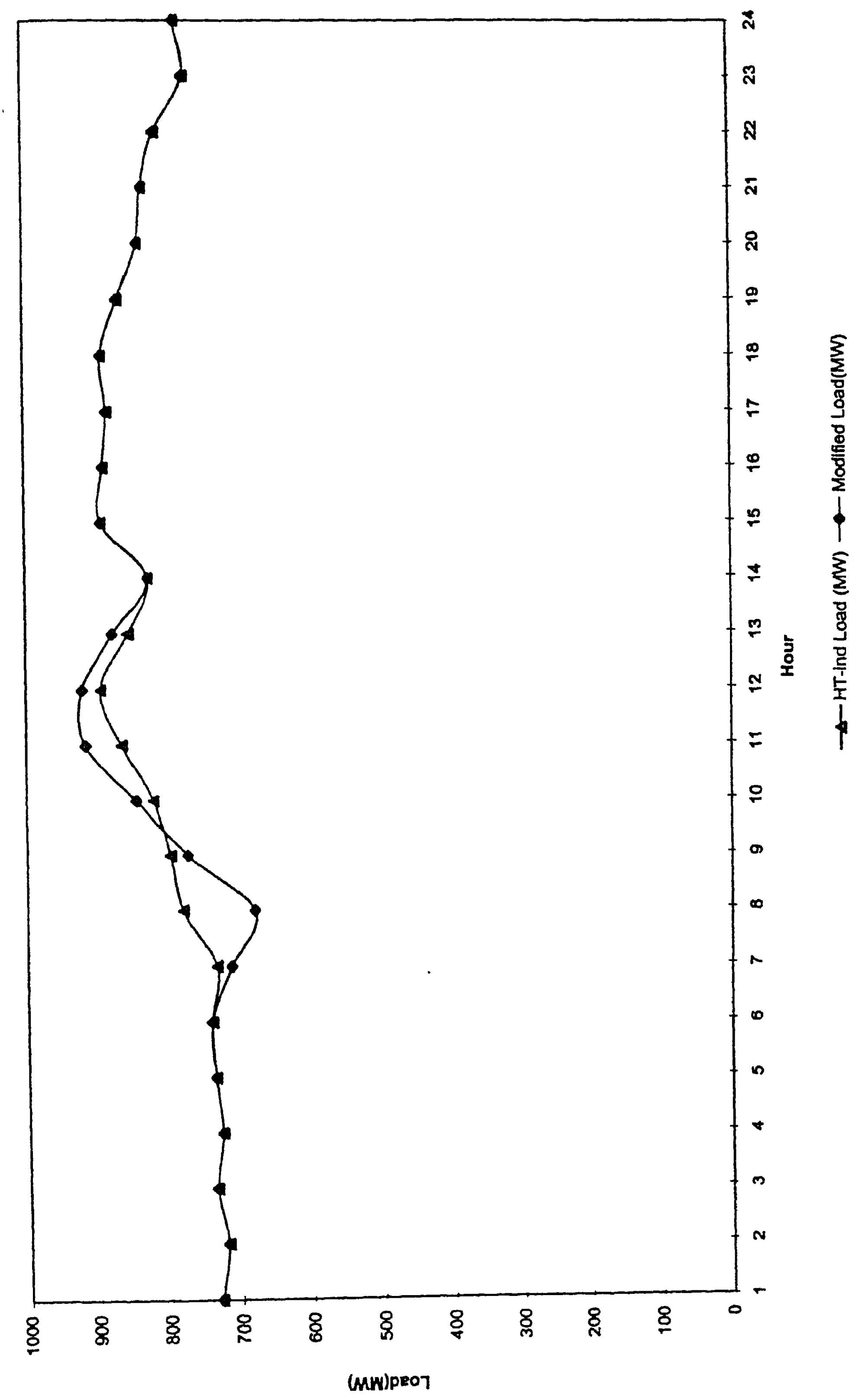


Figure 1.9: Daily load profile-HT Industry



1.10 Agricultural sector

1.10.1 Description of the sector

Agricultural sector is largely unmetered and pays a fixed tariff based on the connected load. It is thus perhaps of greatest interest importance for GEB to understand load in this sector and estimate their impact on the system load.

The average load shape for agriculture is shown below. The agriculture sector accounts for over 40% of total energy sales. Irrigation pumpsets account for major part of the agricultural load. Predominantly agricultural feeder load data were analysed to obtain load shapes for this sector. Since most of the groundwater pumping to meet the irrigation requirement of winter crops the load profile for agriculture is representative for the winter season. The figure 1.10 shows that the agricultural load is maximum between 8 am and 6 p.m. and drops sharply for 3-4 hours but picks up somewhat at night. In view of the supply constraints it would seem that the drop in agricultural load during the evening hours is essentially to accommodate the lighting requirements of domestic sector. Details of the average hours of supply of 3-phase power to the rural areas is given in table 1.12.

FIGURE 1.10

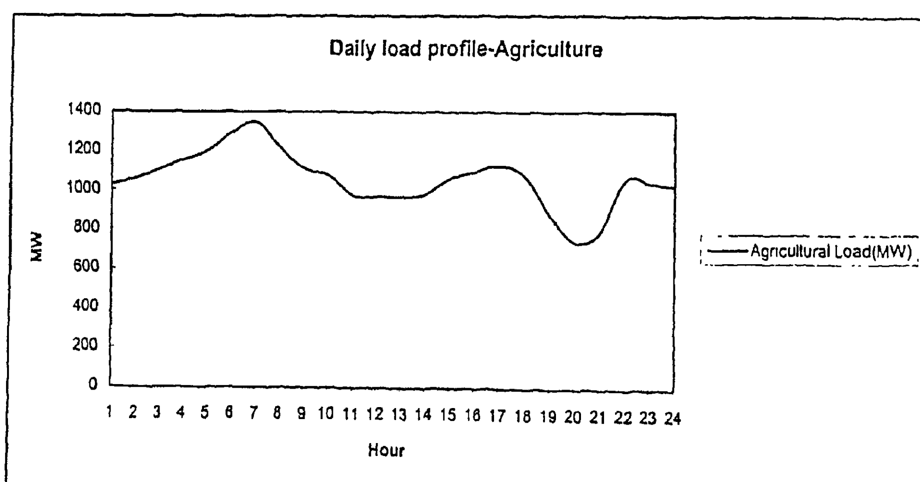


Figure 1.11: System Load Shapes - Agriculture

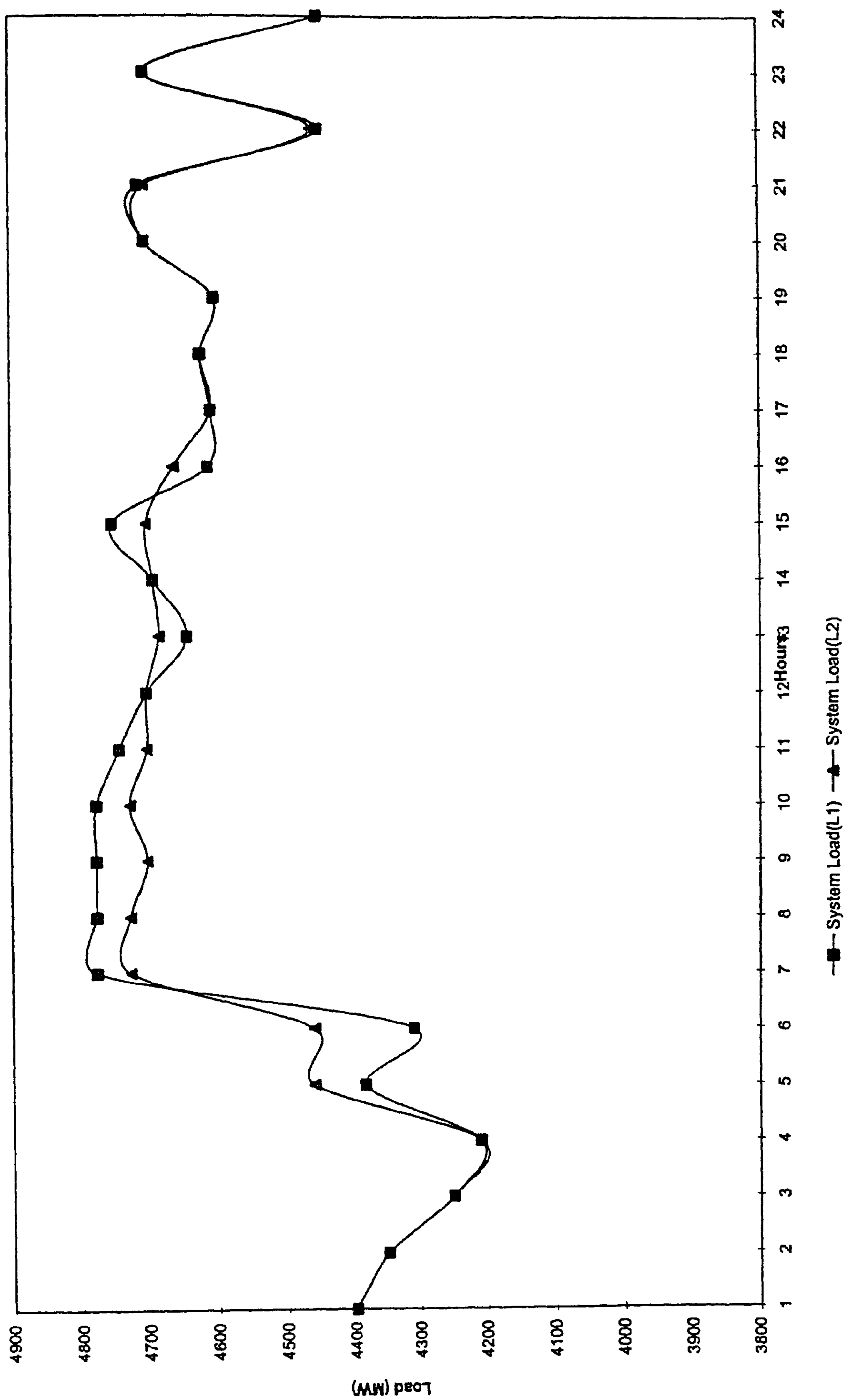


Figure 1.12: Daily Load profile - Agriculture

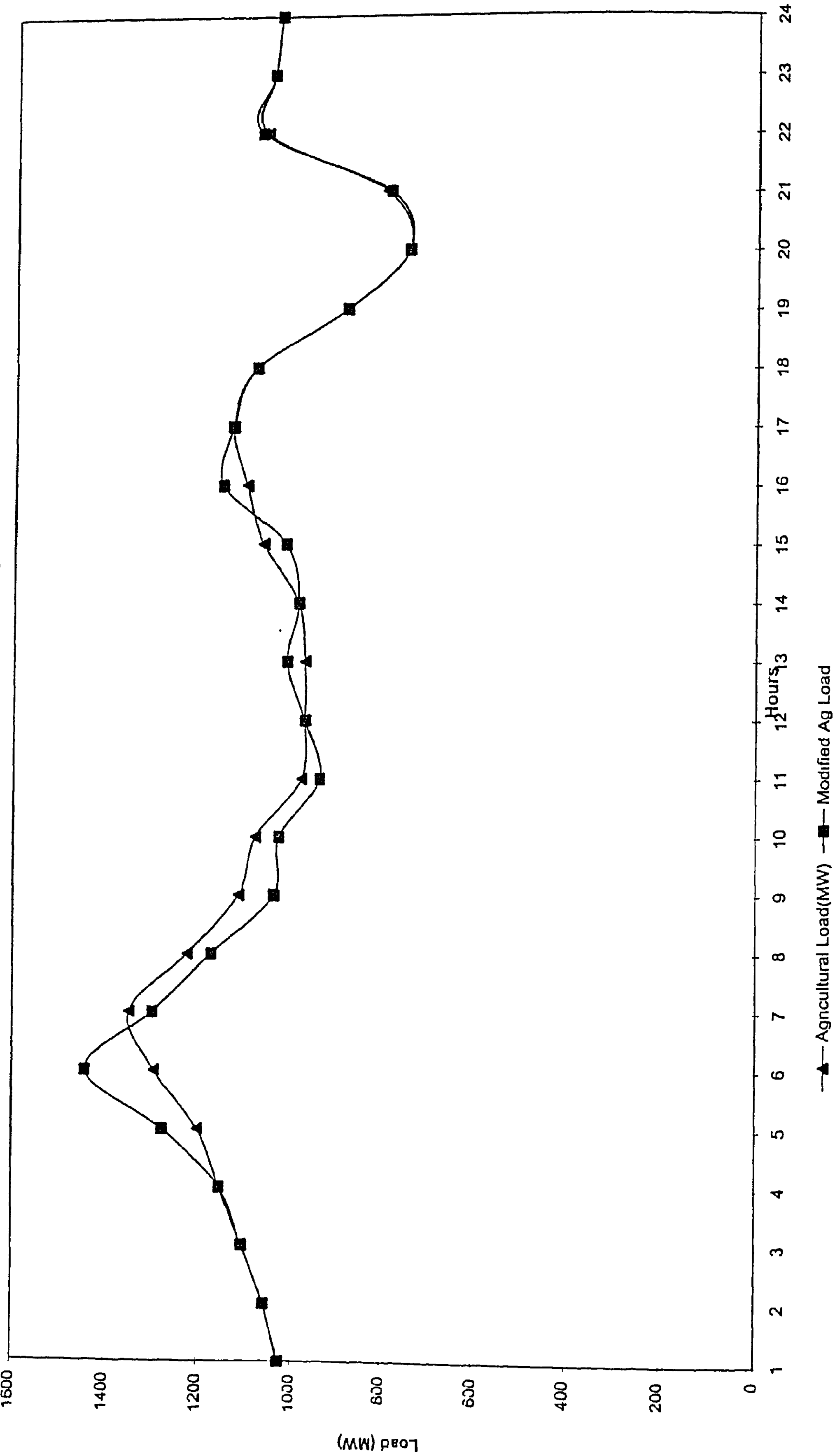


Table 1.12: Details of average hours of 3- phase power supply to rural areas

Month	1987-88	1988-89	1989-90	1990-91	1991-92	1992-93	1993-94	1994-95	1995-96
April	14	17	24	19	16	16	17	14	14
May	19	18	22	21	18	17	17	13	15
June	17	22	22	21	21	18	21	18	15
July	21	23	23	19	21	21	21	22	19
August	15	23	20	22	21	22	18	22	18
September	15	23	20	21	17	20	17	21	15
October	20	19	20	23	15	19	17	14	16
November	17	19	16	22	16	17	13	15	12
December	20	23	14	22	15	17	12	16	13
January	17	24	14	15	15	17	12	15	14
February	22	23	15	17	18	18	13	15	14
March	21	22	21	17	18	19	13	15	13
Average for the year	**18**	**21**	**19**	**20**	**18**	**18**	**16**	**17**	**14**
Power cut %	**No. of days**								
10	-	-	-	20	-	-	-	-	-
15	91	36	41	3	-	-	-	-	-
20	-	-	13	7	84	-	17	-	25
25	118	14	13	-	7	-	-	-	114
30	-	-	-	-	2	-	-	-	-
35	-	-	-	-	8	-	-	-	-
40	43	-	-	28	19	-	-	-	-
50	39	3	-	-	14	-	-	-	-

Source: Generation Department, Information & Achievements, Gujarat Electricity Board, 1995-96.

Analysis of the Load shapes for examining the possibility of shifting the load from peak to off-peak is carried out. These modifications in the load shape is proposed through better rostering techniques and distribution automation. *The modified system*

load shape from the HT-industrial sector would be used here as the base system load shape to evaluate the impact of shifting the agricultural daily demand to the system load shape. The system load shape and the corresponding improved system load shape for GEB is shown in figure 1.11. The modified loading pattern of the HT-industrial sector (figure 1.12) would result in reduction of peak loads from 4775 to 4725 MW and peak hours losses from 956.43 to 936.83 MW. This reduction in peak hour losses (19.6 MW) for 1 hour will reduce the peak hour energy losses by 19.6 MWh. The annual monetary gain accrue to GEB due to reduction in peak hour losses are calculated in Annexure 1.4.

The shifting of daily loads of LT-industrial, HT-industrial, and agricultural sectors would reduce the peak system demand from the existing 4981 to 4725 MW.

1.11 Conclusions

The objective of the load analysis was to identify the consumer groups for DSM programs. Given the almost flat shape of the GEB system load there is little scope for further flattening the load profile. With all measures of shifting the sectoral demands, the load factor is improved from 0.91 as the base case to 0.96 after shifting the industrial and agricultural demands (see Annexures 1.1 to 1.4).

Table 1.13 gives the capacity savings due to reduction in the peak demand, annual energy savings, and resultant annual savings in fuel cost.

TABLE 1.13: Savings from Load Shifting

	Capacity savings due to reduction in peak demand (MW)	Annual energy savings (million units) due to reduction in peak hour losses	Annual savings (million Rs)
LT - industrial sector	43.74	14.43	15.01
HT - industrial sector	40 41	13.33	13.86
Agricultural sector	19.60	1.76	1.83

From Table 1.12, it can be inferred that Time-of-Use pricing does have a role to play in saving peak demand capacity of the GEB, though it may be some what limited due to the relatively high system load factor which is more than 0.80. This point is further discussed in the chapter on pricing options.

Annexure 1.1
Methodology for calculating the peak hour losses

It is important to analyse not only kWh or energy losses but also kW or power losses during peak periods.

An examination of the loading of the daily load shape will provide some basics about the relationship between energy and demand losses. In GEB, T&D losses for the year 1994-95 is 19.25%[1].

Energy loss may be divided among the 24 hourly loads in proportion to the square of the demands. The peak hour would become responsible for:

$$\text{Peak Hour Losses}^2: \frac{(\text{Peak Load})^2 * \text{Energy loss}}{\text{Sum of Square of loads}} \text{ kW}$$

Second column in the worksheets shows the original sectoral loads followed by the modified load shape. similarly, the L1 shows the original system loads and L2 the modified load shape.

[1] Source: Profile of Power Utilities & Non-utilities in India, Council of Power Utilities
[2] Source: Energy Efficiency & Optimisation of Electric Power Distribution System Losses, Energy Department Paper No. 6, July 1982, World Bank

Annexure 1.2

Fuel savings due to reduction in peak demand - LT industrial sector

Hour	LT-ind Load (MW)	Mod LT Load	System Load(L1)	Modified Load(L2)	Square of L1	Square of L2
1	134.76	134.76	4400	4400	19360000	19360000
2	166.76	166.76	4350	4350	18922500	18922500
3	171.81	171.81	4250	4250	18062500	18062500
4	218.98	218.98	4210	4210	17724100	17724100
5	176.87	176.87	4385	4385	19228225	19228225
6	124.93	124.93	4310	4310	18576100	18576100
7	127.01	233.00	4690	4796	21996100	23001616
8	576.15	470.00	4981	4875	24810361	23765625
9	729.79	729.79	4800	4800	23040000	23040000
10	745.79	745.79	4750	4750	22562500	22562500
11	740.52	740.52	4690	4690	21996100	21996100
12	684.37	684.37	4650	4650	21622500	21622500
13	526.44	526.44	4620	4620	21344400	21344400
14	568.90	568.90	4690	4690	21996100	21996100
15	623.95	623.95	4750	4750	22562500	22562500
16	642.30	642.30	4610	4610	21252100	21252100
17	642.30	642.30	4605	4605	21206025	21206025
18	513.84	513.84	4620	4620	21344400	21344400
19	430.50	430.50	4600	4600	21160000	21160000
20	324.91	324.91	4700	4700	22090000	22090000
21	203.07	203.07	4710	4710	22184100	22184100
22	357.09	357.09	4450	4450	19802500	19802500
23	354.21	354.21	4700	4700	22090000	22090000
24	230.38	230.38	4450	4450	19802500	19802500
	10015.62	10015.46	109971	109971	504735611	504696391
		Total energy con		109971		
LF of LT Load shape		0.559			avg load	4582.125
		energy	10015.63		LF	0.919
energy loss over a day (19.25% of the total energy cons)				21169.4175	MWh	
peak hr losses		(Peak load)^2 * energy loss/(sum of square of loads)			1040.58616	MW
DSM-peak losses		(Peak load)^2 * energy loss/(sum of square of loads)			996.845721	MW
difference					43.7404372	MW
savings	(MW savings* 330 days*1000*1 04)		15011718.03	Rs (fuel cost of Rs 1.04/kWh)		(assuming 1 hr peak every day)
annual energy savings				14434344.26	units	

Annexure 1.3

Fuel savings due to reduction in peak demand - HT industrial sector

Time	HT-ind Load (MW)	Modified Load(MW)	System Load (L1)	Modified Sys load(L2)	Square of L1	Square of L2
1	729	729	4400	4400	19360000	19360000
2	719	719	4350	4350	18922500	18922500
3	734	734	4250	4250	18062500	18062500
4	725	725	4210	4210	17724100	17724100
5	734	734	4385	4385	19228225	19228225
6	739	739	4310	4310	18576100	18576100
7	731	710	4796	4775	23001616	22800625
8	779	679	4875	4775	23765625	22800625
9	796	771	4800	4775	23040000	22800625
10	818	843	4750	4775	22562500	22800625
11	863	913	4690	4740	21996100	22467600
12	892	917	4650	4700	21622500	22090000
13	853	874	4620	4641	21344400	21538881
14	823	823	4690	4690	21996100	21996100
15	889	889	4750	4750	22562500	22562500
16	886	886	4610	4610	21252100	21252100
17	880	880	4605	4605	21206025	21206025
18	887	887	4620	4620	21344400	21344400
19	864	864	4600	4600	21160000	21160000
20	836	836	4700	4700	22090000	22090000
21	829	829	4710	4710	22184100	22184100
22	810	810	4450	4450	19802500	19802500
23	770	770	4700	4700	22090000	22090000
24	782	782	4450	4450	19802500	19802500
kWh						
	19366.92	19343.37	109971	109971	504696391	504662631
		LF	0.904		daily energy losses	
			21873	21873		
			7983541367		peak hour losses	
energy loss over a day (19.25% of the total energy cons)				21169.4175		
peak hr losses		(Peak load)^2 * energy loss/(sum of square of loads)			996.845	MW
DSM-peak losses		(Peak load)^2 * energy loss/(sum of square of loads)			956.432	MW
difference					40.412	MW
savings	(MW savings* 330 days*1000*1.04)		(assuming 1 hr peak every day)		13869676	Rs (fuel cost of Rs 1.04/kWh)
annual energy savings					13336226.9	units

Annexure 1.4

Fuel savings due to reduction in peak demand - Agricultural sector

Hours	Agricultural Load(MW)	Modified Avg Load	System Load(L1)	System Load(L2)	Square of L1	Square of L2
1	1027.71	1027.71	4400	4400	19360000	19360000
2	1058 86	1058.86	4350	4350	18922500	18922500
3	1105.57	1105.57	4250	4250	18062500	18062500
4	1152.29	1152.29	4210	4210	17724100	17724100
5	1199.00	1274.00	4385	4460	19228225	19891600
6	1292.43	1442.43	4310	4460	18576100	19891600
7	1346.93	1296.93	4775	4725	22800625	22325625
8	1221.43	1171.43	4775	4725	22800625	22325625
9	1114.29	1039.29	4775	4700	22800625	22090000
10	1078.57	1028.57	4775	4725	22800625	22325625
11	978.57	938.57	4740	4700	22467600	22090000
12	971.43	971.43	4700	4700	22090000	22090000
13	971.43	1011.43	4641	4681	21538881	21911761
14	985.71	985.71	4690	4690	21996100	21996100
15	1064.29	1014.29	4750	4700	22562500	22090000
16	1100.00	1150.00	4610	4660	21252100	21715600
17	1128.57	1128.57	4605	4605	21206025	21206025
18	1078.57	1078.57	4620	4620	21344400	21344400
19	878.57	878.57	4600	4600	21160000	21160000
20	742.86	742.86	4700	4700	22090000	22090000
21	792.86	782.86	4710	4700	22184100	22090000
22	1056.86	1066.86	4450	4460	19802500	19891600
23	1041.43	1041.43	4700	4700	22090000	22090000
24	1026.00	1026.00	4450	4450	19802500	19802500
	25414.21	25414.21553	109971	109971	504662631	504487161
LF	0.79		avg load	4582.125		
			LF	0.969761905		
energy loss over a day (19.25% of the total energy cons)			21169.4175			
peak hr losses		(Peak load)^2 * energy loss/(sum of square of loads)			956.432912	MW
DSM-peak losses		(Peak load)^2 * energy loss/(sum of square of loads)			936.833508	MW
difference					**19.5994047**	MW
savings	(MW savings* 90 days*1000*1.04)		(assuming 1 hr peak every day)		**1834504.28**	**Rs**
annual energy savings					**1763946.42**	**units**

CHAPTER 2

CHAPTER 2

Identification and screening of energy efficient technologies (EETs) for various end-uses

2.1 Background

The power situation in Gujarat, and for that matter, in India demands a serious look at the future options available to bridge the gap between the supply and demand. The traditional approach has been to augment capacity by building new power plants, but has a drawback in that it needs huge capital resources. A side effect of this approach is the degradation of the environment.

An alternative approach to create capacity has gained favour in recent years, namely Demand Side Management (DSM). The DSM approach considers that every MW saved is equivalent to a MW generated. In fact, some people would even argue that it is greater than a MW generated when the effects on the environment are taken into account.

Energy efficient technologies (EETs) seek to provide the same output levels as the conventional technologies, but at a lower rate of energy consumption. Though these EETs cost more than the conventional technologies, the increased cost is usually more than compensated through the energy savings achieved over the life time of the equipment.

2.2 Methodology

This chapter details the analysis carried out to determine the most attractive DSM options for implementation in Gujarat, in the service area of GEB.

A literature review was carried out and several EETs with potential to save electrical energy and reduce peak demand were identified. A brief description of each technology is also provided in the text.

After the literature survey was conducted, data such as percent energy saving, incremental cost of the measure, coincidence factor, annual operating hours, etc. was gathered for each technology to conduct screening on the basis of cost criteria. Only the technologies which were found to be cost effective were selected for further screening.

At this point the selected technologies were screened to identify those which would not be applicable to the areas served by GEB so that they could be dropped from the short list. A normalisation and weightage matrix was developed to rank the different technologies in order of their suitability. The ten top ranking technologies were selected to be the most attractive options for GEB's service area.

2.3 Energy efficient technologies

2.3.1 Lighting

In Gujarat, four types of lighting systems are used - incandescent, fluorescent, mercury vapour and sodium vapour. The lighting efficiency can be increased through use of more efficient lighting techniques. Some of these efficient lighting measures are: increased use of daylight, use of better lighting fixtures and use of lighting control systems for the same or marginally greater light output. Some of the lighting conservation measures having largest potential of saving are:

- Replace incandescent lamps with compact fluorescent lamps.
- Replace incandescent lamps with fluorescent tube fixtures.
- Replace TL fluorescent tubes with TLD fluorescent tubes.[1]
- Replace incandescent lamps with circular fluorescent lamps.
- Install electronic ballast or low loss ballast when conventional ballast wear out.
- Use HPSV instead of HPMV.

a. Compact fluorescent lamps

Compact fluorescent Lamps (CFLs) are more efficient than the incandescent lamps. A 60 W incandescent lamp can be replaced by a 16 W CFL reducing electricity use by 73% and last 8 times longer than incandescent lamp. Incandescent lamps are inefficient as only about 10% of the power is converted to visible light. An incandescent lamp with a rating of 60 W has an output of 700 lumens, a life of 1000 hours and its selling price is about Rs 10.00. A 16 W compact fluorescent lamp has an output of 900 lumens, a life of 10000 hours and

[1] TL fluorescent tubes have a diameter of 1.5" and are rated at 40 watts. The TLD lamps have a diameter of 1.25" and are rated at 36 watts

is priced at about Rs 300.00. CFL is most suitable for the residential and commercial sectors. The initial high cost of a CFL and the quality of the power supplied are major limiting factors to its use in India.[2]

b. Fluorescent lamps

In India most of the fluorescent lighting is at 40 W plus a 12-15 W magnetic ballast. Fluorescent lamp can be used to replace incandescent lamps. A 60 W incandescent can be replaced by a 18 W TLD (plus 14 W for ballast) saving more than 40% of electricity and providing 50% more light output.

Better version of fluorescent lamp is also available in India, which includes 36 W Warm white thin tube light. This thin fluorescent lamp (36 W Warm white) delivers 10% extra lumens compared to 40 W cool daylight fluorescent lamp. In India 36 W warm white fluorescent lamps are not used very widely because of lack of awareness in its energy saving capacity. However, recently manufacturers are promoting use of 36 W fluorescent lamps.

c. Replacement of magnetic ballasts by electronic or low loss ballasts

Each fluorescent fixture has a ballast which provides a high voltage to initiate the discharge and limits the current. The losses in the conventional ballast is of the order of 12-15 W compared to 1-4 W Losses in the electronic ballast. Indian ballasts use aluminium wire, low quality lamination material and have low power factor. The electronic ballasts have better power factor and a life of about 20 years as opposed to magnetic ballasts which have a life of 5 years. The cost of a magnetic ballast is Rs 60.00 and that of an electronic ballast is about Rs 310.00. Over the long run, as the quality of Indian electronic ballasts improves, and as existing ballasts need replacement, this measure should be appropriate for nearly all fluorescent fixtures in India. The only consideration in the use of electronic ballasts in India is quality of power supplied, i.e. large fluctuations in voltage, as it affects the working life of the ballast.

2 Just as ordinary fluorescent lamps can not ignite or continue burning at low voltages, the same also holds true for CFLs.

Low loss ballasts are electro-magnetic hybrid ballasts, and though they consume more energy than the electronic ballasts (about 5 W per ballast), they are priced at just about Rs 180.00, which makes them very attractive.

d. High pressure sodium vapour lamps

Lighting by high pressure sodium vapour lamps (HPSV) is preferable as it consumes only half as much power as mercury vapour lamps (HPMV) and only 20% as much power as incandescent lamps for the same light output. Thus replacement of HPMV with HPSV results in a saving of about 40%. A 250 W high pressure mercury vapour lamp gives 13,000 lumen of light, whereas a HPSV of 250 W gives double this lumen output. Hence, a 250 W (plus 35 watts for the ballast) HPMV can be replaced by a 150 W (plus 21 watts for the ballast) HPSV with a modest increase in light output. HPSV lamps and their required ballasts are produced by several Indian manufacturers.

The main limitation for the HPSV lamps is their low colour rendering index (CRI[1]). Most HPSV lamps have a CRI ranging between 20 and 25, the light being emitted by these lamps being mainly of reddish yellow colour. Hence, these lamps are mostly suitable for areas where colour discrimination is not a critical factor.

In recent years, two types of high colour rendering sodium lamps have been introduced in India, having a CRI of around 60 and 85 respectively. Though these lamps allow colour distinction, this improvement in colour rendering has been achieved at the cost of their efficacy and life.

Even greater savings are possible through the use of low-pressure sodium vapour lamps. Although these lamps have the highest efficacy of the different types of lamps in use today, they are not widely used due to the colour of the light emitted. Their extremely yellow light makes colour discrimination impossible, thus limiting their applicability.

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[1] The CRI is an index where the relative ability to distinguish colours in lights emitted by different lamps is compared. An incandescent lamp is taken as the base for the comparison and given a CRI of 100.

e. **Other options**

The introduction of programmable timers/photo cells for street lighting can be carried out at suitable locations. These timers/photo cells will ensure that the street lamps will be automatically switched off and on during day and night time respectively. The timers can be adjusted to suit the varying day light hours of summer and winter.

Ultrasonic or infrared occupancy sensors can be used in classrooms, public lavatories, individual offices, etc. to turn off lights and other equipment automatically when the space is empty.

Daylighting controls are available which automatically dim the lights to compensate for increased natural light as the day progresses, and the reverse in the evenings. This measure may be suitable for open space office plans.

Reflective light fixtures are a simple energy conservation option. Reflective films using both anodised aluminium and silver film reduce light absorption within the fixture, emitting up to twice the light per watt of power compared to ordinary fixtures.

2.3.2 High efficiency fans

Fans are one of the largest user of electricity in the domestic sector served by GEB, as has been shown in Chapter 1 on Demand and Load Curve Analysis. This includes both ceiling fans and table fans. The efficiency of fans can be improved either by use of more efficient motors or electronic fan speed control.

a. **More efficient fan motor**: The fan motor efficiency can be improved by 10-15%, thus reducing the energy consumption by 10-20% with a price difference of about 30%. The efficiency of fans and the motors can be improved by using aerodynamically designed fans and improved impeller designs.

Electronic speed control: Fans are not always operated at full speed. Most Indian fans use resistance type fan speed regulators which reduces fan speed by introducing resistance into the fan circuit. This resistance results in considerable energy losses in the form of heat. An alternative, is to use electronic controls. Electronic regulators reduces the energy losses by 10-20% when the fan is operated at low speeds. However, it is found that electronic controllers used in India introduce harmonics and thus reduce the power factor.

2.3.3 Refrigerators

Refrigerators account for about 16% of the total electricity use by the domestic sector. Efficiency of refrigerators used in India is very low. Single door, manual defrost refrigerators are the most commonly used refrigerators in India, though the two-door frost free models are gaining in popularity. In areas suffering from frequent power outages, people prefer the manual defrost refrigerators as in times of disruption in supply, the thermal mass in the form of ice, provides cooling (TERI, 1995).

A typical 165 litre Indian refrigerator consumes approximately 540 kWh/year. In comparison a Brazilian model of about 225 litres uses 410 kWh/year and a Korean 200 litre model uses approximately 240 kWh/year [10]. Efficient refrigerators can save 30-50% energy and are cost effective too, though they have high initial cost.

High efficiency refrigerators are currently not available in the Indian market as they use a different design of compressors which is very sensitive to the quality of power which is supplied. Till such time as the electric utilities in India can ensure power supply at the rated voltage and frequency, any increase in the efficiency of Indian refrigerators can only come through better insulation techniques. Since the technology is not available in India, no further analysis was carried out.

2.3.4 Air conditioning

Room air conditioners often represents the heaviest load for individual households using AC. Therefore, even a modest improvement in efficiency can result in substantial saving for individual consumers. Also, with rising income levels, demand for ACs is rising and thus their efficiency improvement has a significant impact on future demand. Efficiency of room air conditioners is measured with an energy efficiency ratio (EER) which is the Btu of cooling output divided by the watts of power input. Bureau of Indian standards calls for an EER of 6.6-7.0. However, many units are sold with EER perhaps as low as 5.0. Based on experience in other countries, it appears that an EER level of 9.0 can be obtained in India.

Many measures are available to improve the efficiency of central HVAC systems. These include reducing heat gain into the building, improved efficiency equipment, improved controls, use of more efficient distribution systems such as variable air volume (VAV) systems. VAV systems need complex and expensive control systems to enable inter-action between the thermostat in a zone and the air delivery unit in the zone. Due to this reason, they are not currently used in India.

Thermostats and other controls turn specific pieces of equipment on and off. One particularly sophisticated control, a building automation system, allows the user to reduce energy use by operating equipment in the most efficient manner. Among a wide range of functions, such systems can reduce equipment operation during unoccupied periods, optimise the distribution of cool air to the sections of the building needing it the most, and turn equipment on in stages in order to optimise operating efficiency. Less sophisticated controls are also available, which cost less, but result in somewhat lower energy savings.

2.3.5 Direct control for central air-conditioners

Direct control for air-conditioners use remote control to switch off the air-conditioners during peak load periods by utilities. Incentives are to be provided to consumers participating in this program for installing the remote control sensor on their air-conditioners. This technique has yet to be introduced

in India. Cost of installation of this remote control equipment is a major problem as most of the utilities are not in a position to invest in additional costs.

2.3.6 Evaporative coolers

Evaporative coolers or desert coolers provide low cost form of air conditioning in regions with low humidity. It blows warm room air across a spray of water, causing the water to evaporate, which cools the air. A typical cooler uses 20% more energy than a unit meeting BIS's voluntary standards. The 20% higher efficiency level can be achieved at an incremental cost of Rs 500 by improving the efficiency of the fan motor and the water circulating pump.

2.3.7 Water heating

In hotels central water heating technology is adopted in India. In these cases it would be beneficial incorporating energy efficient technologies.

a. **Water heater retrofit:** Three main measures for increasing efficiency of water heaters are insulating blankets, thermostat setbacks and insulating bottom boards. A popular means of lowering water heater energy use involves covering the tank with an insulating blanket made of fibre glass and backed with vinyl. These blankets reduce the heat loss through the walls of the tank. The blankets can be used to cover the sides and top of the water heater, leaving the bottom uninsulated. Bottom boards can be used to limit heat losses through the bottom of the tank. Insulation of the hot water pipes also reduces heat loss. Heat traps can be used to reduce piping heat losses by interrupting the normal convection patterns that occur when all water in a line is not at the same temperature. Heat traps are installed on inlet and outlet water connections to the tank to limit or prevent heated water from continually rising in the pipes resulting in heat being lost through pipe walls during standby periods. Another option is the thermostat control. Heat lost by the water heater tank and associated piping increases directly as the difference in ambient air and water tank temperature. Lowering the thermostat setting is a very simple way to decrease heat losses. Savings directly reflect the extent to which the actual water temperature is lowered.

b. **Heat pump water heaters**: The heat pump water heater operates on a vapour compression cycle similar to that of a window air conditioner. The unit removes heat from surrounding air and transfers that heat to the domestic water supply. An integral heat pump water heater is a single packed unit consisting of heat pump components and a standard electric water heater tank containing resistance heating elements. The add-on unit is external to the water heater tank and is designed for being added to an existing electric water heater. With the add-on unit, water is drawn from a conventional water heater tank, piped through the heat pump unit, and returned to the water heater tank. Performance of both types of units is a function of the temperature and humidity of the air surrounding the heat pump water heater. During unit operation the temperature and humidity levels of the air are lowered as the heat is removed and transferred to the water supply.

c. **Heat recovery water heaters**: They recover a portion of the superheat available from a vapour compression cycle. The units can be installed on heat pumps as well as air conditioners. The primary component of the heat recovery unit is a double walled heat exchanger in which energy is transferred from hot refrigerant gas to the potable water supply. The refrigerant line to the heat exchanger is connected between the compressor and condenser of an air conditioner or heat pump. Hot refrigerant from the compressor enters the heat exchanger where it transfers a portion of its heat to the domestic water supply before passing on to the condenser. Unit operation is generally triggered by air conditioner or heat pump compressor operation. Once the refrigerant being discharged by the compressor reaches a certain temperature, the water circulating pump begins operating and continues until either the compressor stops or until all available water has been heated and the water heater thermostat has been satisfied. Installation of a heat recovery unit on an air conditioner can result in improvements in air conditioner efficiency. When heat recovery unit is installed on a heat pump, the same effect can result in the cooling mode. However, when the heat pump is

operating in the heating mode, the heat recovery unit increases the load on the heat pump by using heat that would otherwise have contributed to space heating needs. Performance of heat recovery water heaters is best when there is a high coincidence between hot water use and air conditioner operation. Without this coincidence the stored water is quickly heated to the desired temperature, and heat recovery operation ceases. Superheat may still be available for retrieval but there is no place to store the heat. In some cases a second storage tank is added so that more water can be heated and stored for later use.

2.3.8 Control techniques

Control techniques can mainly be used with the purpose of optimising existing capacity, namely to carry out peak clipping, valley filling, load shifting and flexible load shaping. Control techniques can be classified as direct load control technique, local control technologies and distributed control technologies.

In direct load control techniques the utility controls the customer loads without the customer interaction, e.g. power line carrier or ripple control systems used in space heating, water heating, time-of-use meters etc.

The use of distributed technologies allows control over loads by customers in communication with utilities. This can be applicable to large industries where the utility can have special contracts such as interruptible loads, by using telephone lines.

The use of local control technologies allows the customer to control the loads. A circuit breaker is installed at the customers premises which interrupts power if customer exceeds contracted power. Timers, thermostats, photo-cells and occupancy sensors also fall under this category.

Home automation systems, coupled with two way communication systems offers new load management capabilities. All types of appliances (energy, entertainment, security, information) communicate between themselves and are controlled in an integrated way. This application needs development in

communication standards and protocols which allow optimal use of appliances in terms of comfort and savings. This technology is yet to be introduced in India. Here cost of introducing this technology, low tariff structure and the technology have been the barriers to its accomplishment in India.

2.3.9 Agricultural pumps

Several surveys carried out to measure the efficiency of pumpsets have revealed poor operating efficiencies of both electric and diesel pumpsets. Surveys carried out by the Institute of Co-operative Management in Gujarat with support from NABARD, PCRA, GEB and REC in the state of Gujarat, indicate that nearly 90% of the agriculture pumpsets installed are faulty and consume 150-200% more electricity than that required for properly selected pumpsets. Retrofitting of 300 pumpsets carried out under this study, resulted in reduction in total connected load from 4129 HP to 2125 HP, i.e. savings of 48%. Reasons for high electricity consumption in agriculture pumpsets include:

- Improper selection of pumpset size. A study conducted in the state of Gujarat, revealed that 50% of the pumpsets had ratings that were 50-75% higher than the required rating, resulting in underloading of the pumpsets.
- Improper selection of foot-valves, undersized delivery pipes, improper pipe fittings etc., causing high frictional losses.
- Use of pumps with low efficiency.

These to a large extent can be attributed to lack of information and knowledge on part of the farmers, lack of standardisation, and ineffective monitoring and control on the part of the financial institutions. Also, electricity supply to agriculture sector in India, is largely unmetered. Agriculture consumers are charged for electricity based on the capacity of pumpset installed (HP of pumpset) rather than hours of usage of the pumpset. Such a system, thus provides no incentive to limit the hours of operation nor to improve pump efficiency.

Improved efficiency of agricultural pumps can be achieved through measures like: replacement of undersized pipes and fittings, proper sizing of motors and pumps, use of energy efficient motors and pumps, use of pumps with better suction lift characteristics, operation of pumps at correct speeds, efficient coupling of motors and pumps, power factor correction and better water management. Three major efficiency measures are:

a. **Pump metering:** In India, presently agricultural pumps are not metered. The agricultural sector have a flat rate tariff structure which is highly subsidised. This tariff structure does not promote energy conservation, leading to use of inefficient pumps. Promotion of energy conservation can only be obtained by introducing a fare tariff structure by which consumers are motivated to use energy efficiently. Installation of meters could reduce electricity use by 5%. This figure is based on discussions with experts and is much lower than the approximately 15% savings achieved in the United States when tenants were billed for their electricity consumption (Rosenburg, 1984).

b. **Rectification of existing pumps:** A typical pump is linked with a belt to a motor, foot valves and return and supply pipes with high friction losses. Retrofit measures include replacement of the existing foot valve, return and supply lines with low friction equivalents. This retrofit package reduces electricity use by 30-50%. As the pump-size increases, cost effectiveness of this package increases.

c. **High efficiency pumpsets:** If worn out pumpsets are replaced by efficient ones, savings of approximately 20% can be achieved.

2.3.10 Variable speed drives

Fluids driven by pumps, fans and blowers are usually regulated by throttling. This is an inefficient method of control and results in significant energy losses. One efficient method to control the speed of the motor is use of variable speed drives. Variable speed drives are electronic devices that are placed between the motor and the power supply. Variable speed drives permit continuous regulation

of motor speeds which can lead to substantial electricity savings, particularly when there is partial load operations during a large portion of the duty cycle. Variable speed drives have significant scope in paper, chemical, fertiliser, pharmaceutical and cement industry. The life of variable speed drives is approximately ten years. Variable speed drives are manufactured in India. The companies manufacturing variable speed drives generally import electronic components into India, and then assemble them into a drive. They are presently fairly expensive in India, and as a consequence are primarily used with large motors.

2.3.11 Energy efficient motors

Electric motors account for 60-70% consumption of electricity in the industrial sector. Motors with improved design and material giving about 3-5% higher efficiency are referred to energy efficient motors. Motors supplied by small scale industries have very low efficiency. The average life of a motor is about 30 years. A few industries have already begun adopting energy efficient motors. It is cost effective in many cases to purchase a more efficient motor at the time an existing motor needs to be rebuilt. Oversizing of motors is very common because of the low first cost, uncertainties regarding future load, starting stress on motor and fluctuations in line voltage. Oversizing leads to inefficiencies especially when operating at less than 50% of the rated load. For many motor applications, there are substantial energy losses during part load operations. Various technologies for motor speed control and energy conservation during part load operations are available, including eddy current couplings, hydraulic couplings, DC motors with rectifier or thyristor controls, AC slip ring motors and electronic variable frequency drives. Variable frequency drives (VFDs) employing silicon controlled rectifiers and thyristors are the most efficient means of controlling motor speed over a wide range of loads.

From the manufacturing perspective the primary barrier to producing energy efficient motors is cost. There are basically four different types of losses in motors: electrical, magnetic, mechanical and stray losses. Each of these losses can be reduced by simple manufacturing processes, though each procedure involves somewhat higher production costs. The I^2R losses, occurring in the

stator and rotor can be reduced by using lower resistance materials, such as larger diameter copper windings. Magnetic losses occurring in the steel lamination of the stator and rotor are due to eddy current and hysterisis. These losses can be reduced by using larger cross-sections of iron in the stator and rotor, as well as thinner laminations and improved magnetic materials. Mechanical losses appearing as friction in the bearings and also losses in the cooling fans can be reduced by using higher quality bearing assemblies and improved fan designs. Stray losses take many forms, including leakage flux, non-uniform current distribution, imperfect air-gaps and irregularities in the air gap flux density. By optimising the design and manufacturing to tighter tolerances, the efficiency can be improved.

The efficiency of motors manufactured in India vary from manufacturer to manufacturer. In particular, some of the small scale manufacturers who make only small motors produce motors with lower efficiencies than manufacturers in the organised sector. In addition, several manufacturers produce two line of motors - a standard efficiency line and a high efficiency line. A primary reason for low sales of high efficiency motors in India is that they cost more than the standard efficiency motors.

2.3.12 Industrial cogeneration

Cogeneration implies simultaneous generation of power and heat through a single fuel source. Cogeneration schemes have potential in textile, paper, cement, fertiliser, sugar, chemicals and pharmaceutical industries. High initial investment and utility policy are the main barriers to implementation of cogeneration in India. With revision of the government policies towards cogeneration, cogeneration is becoming increasingly popular in India.

Industrial cogeneration as a DSM option is discussed and analysed in depth in Chapter 5.

2.3.13 Centrifugal compressors

Centrifugal compressors are preferable to reciprocating compressors for large refrigeration loads. The main barriers in installation of centrifugal compressors

are price and maintenance. Temperature limitation is also a problem as the market is not aware that two stage and multiple stage centrifugal compressors are available. Presently, centrifugal compressors are manufactured and also are being used in India.

2.3.14 Improved electric arc furnaces

Electric arc furnaces can be retrofitted with technologies like scrap preheating, oxyfuel burners, bottom tapping, computerised control and automation. These improved electric arc furnaces are being manufactured and used in India.

2.3.15 Industrial processes

Process heating and electrolytic processing are the second largest industrial electricity end-use.

a. **Chemicals**: Certain chemical production processes are energy intensive and present opportunities of savings. Chlor-alkali industry accounts for about 4% of industrial electricity consumption in India. Ordinary diaphragm cells consume 15% less power than conventional mercury cells, while membrane process consumes even less power. Since all new plants have to use the membrane process rather than the mercury cell process, this technology has not been considered for further analysis.

b. **Aluminium**: Primary aluminium production is by the Hall process. The measures that can be employed in the Hall process include: optimising the cross section of bus-bars, changing from bolted to welded joints, better control of cell operating conditions, better control of electrolyte composition and improved insulation.

   GEB's service area does not have any aluminium smelters, thus no further screening was carried out for this technology.

2.3.16 Other Practices

a. Good housekeeping practices

Good housekeeping involves actions such as switching off unwanted electric lights and machines, reducing leakage of compressed air, proper sizing of motors, improved day lighting, reducing chilled water usage, improved monitoring and control. Monitoring and management is essential for the same. Above all, an energy waste avoidance culture is essential in India.

b. Pricing

There is a wide variation of load in power plants. If peaking plants are built, they remain idle for the off-peak periods and do not earn return during these hours. Hence, this option is costly as it involves building new plants. Load levelling and load shifting help in better utilisation of existing capacity. This can be promoted by use of tariff related options like time of use tariffs. Here a differential tariff structure is suggested instead of a constant energy charge, which is proportional to the plant load. The demand charges remain constant.

Certain sectors like the agricultural sector have a flat rate tariff structure in India. This tariff structure does not promote energy conservation, leading to use of inefficient pumps. Some others in the lower domestic sector are granted single point connection at highly subsidised rates. These consumers might increase the number of points by multiple connections and continue to either receive free power or at highly subsidised rate. Promotion of energy conservation in India can only be obtained by introducing a fare tariff structure by which consumers are motivated to use energy efficiently.

Various pricing options for promoting DSM are discussed in detail in Chapter 4.

c. Photovoltaic and solar-thermal technology

Potential DSM markets for these technologies exist for air-conditioning and water heating. The advantage is available when PV is used in conjunction with electric devices that typically operate intermittently. Air conditioners and water heaters are devices which operate intermittently, making them technically compatible with PV and can be used as a DSM technology. Furthermore, these

end uses fall within higher priced range of a utility DSM demand curve. PV may provide an additional advantage of maintaining service levels above that of traditional DSM options by maintaining higher water temperature and better circulation of cold air in a building.

So far, flat plate collector technology is commonly used as an option for solar-thermal water heating. But, the evacuated tube collector technology is more reliable, has greater life and the cost/litre of hot water is lower using this technology. Evacuated tube collector water heaters are manufactured in India and also are being used here.

d. Information dissemination

Creating awareness amongst consumers by itself can help reduced end-use consumption by avoiding wastage. In cases where first cost is a problem, providing incentives is an attractive method for encouraging use of efficient technologies to avoid wastage in India.

e. Energy labelling and standards

One of the important tools to increase consumer awareness is through energy labelling. Labelling is expected to provide the consumer with more information on energy consumption and is expected to encourage manufacturers to move towards products that are energy efficient, and also encourage consumers to purchase such products.

The technologies for which adequate information was available to conduct a detailed analysis are listed in Table 2.1 along with the information needed to conduct the analysis.

2.4 Cost analysis

2.4.1 Cost of Saved Energy

Using the incremental cost for replacement of an existing technology with an energy efficient technology, a discount rate of 12%, over a 20 year period, the cost of saved energy (CSE) was obtained. CSE gives the unit cost for the measure per kWh saved.

CSE provides a method by which the costs for different technologies can be compared amongst themselves and with the marginal cost for generation of electricity.

The CSE is calculated using the following formula:

$$CSE\ (Rs\ /\ kWh) = \frac{Incremental\ Measure\ Cost\ *\ Capital\ Recovery\ Factor}{Annual\ kWh\ Savings}$$

Measure costs are primarily initial costs (incremental), but where ongoing costs are substantial we have included them in the analysis. The capital recovery factor can be thought of as the annual payment on a loan used to finance an efficiency measure, assuming an interest rate equal to the discount rate, and a loan term equal to the measure life.

The CSE was compared to the average cost of supplying electricity to GEB's consumers. The Planning Commission Report 1994 on the "Working of the State Electricity Boards", estimates this cost to be Rs 1.78 per kWh. If the CSE for any EET is higher than this cost, it is not cost effective to install the EET as generating the same power is cheaper.

Table 2.2 gives the CSE for the various EETs. The proposed replacement of conventional fan regulator with electronic speed control had a CSE of Rs 2.16 and was thus omitted from the list of EETs selected for further evaluation.

2.4.2 Cost of Saved Demand

Besides saving energy, EETs also reduce the demand for electricity which helps in either deferring or eliminating the need for building new power plants.

The cost of saved demand (CSD) was calculated using the following formula:

$$CSD\ (Rs\ /\ kW) = \frac{Incremental\ Measure\ Cost}{Avg.\ kW\ Savings\ *\ Peak\ Coincd.\ Factor\ *\ T\&D\ Factor\ *\ 1\ /\ Capacity\ Utilis.\ Factor}$$

CSD was calculated using 60% capacity utilisation factor, 19.25% T&D losses (T&D factor = 1.1925), and a period of 20 years (for measure cost). For measures having life span shorter than 20 years, discounted equipment replacement costs were included in the calculations. The peak coincidence factor is the estimated proportion of equipment that is actually operating during GEB's period of peak demand.

Table 2.1: List of Energy Efficient Technologies

S. No.	Existing Technology	Proposed Technology	Sector	Size of Unit for Analysis	Energy Reqmt. for Old Tech. kW	Energy Reqmt. for New Tech. kW	Measure Applicblty. %	Coinc. Factor %	Optg. Hours per Year	Inc. Cost of Measure Rs.	Savings for EETs %	Measure Life Years	Connected Load MW	System Load GWh
1.	Std. eff. Agri. pumps	High eff. Agri. pumps	Agri	4 kW	4.000	3.200	60%	16%	3,000	2,000	20%	15.00	3722.54	8,652.00
2.	Unmetered agri. pumps	Metered agri. pumps	Agri	4 kW	4.000	3.800	100%	16%	3,000	400	5%	20.00	3722.54	8,652.00
3.	Incandescent lamps	Compact Fluorescent	Com	60 Watt	0.060	0.016	15%	90%	3,000	300	73%	3.33	89.32	35.47
4.	Incandescent lamps	TLD Fluorescent	Com	60 Watt	0.060	0.032	50%	90%	3,000	115	47%	1.67	89.32	35.47
5.	TL Fluorescent	TLD Fluorescent	Com	40 Watt	0.054	0.050	100%	90%	3,000	0	7%	1.67	471.57	187.25
6.	Incandescent	Circular Fluorescent	Com	60 Watt	0.060	0.022	15%	90%	3,000	75	63%	2.33	89.32	35.47
7.	Magnetic ballast	Electronic ballast	Com	40 Watt	0.054	0.042	100%	90%	3,000	250	22%	20.00	471.57	187.25
8.	Magnetic ballast	Low loss ballast	Com	40 Watt	0.054	0.045	100%	90%	3,000	120	17%	10.00	471.57	187.25
9.	HPMV lamp and ballast	HPSV lamp and ballast	Com	250 Watt	0.285	0.171	70%	90%	4,000	465	40%	6.00	10.56	4.20
10.	Incandescent lamps	Compact Fluorescent	Dom	60 Watt	0.060	0.016	15%	60%	2,000	300	73%	5.00	762.05	578.05
11.	Incandescent lamps	TLD Fluorescent	Dom	60 Watt	0.060	0.032	50%	60%	2,000	115	47%	2.50	762.05	578.05
12.	TL Fluorescent	TLD Fluorescent	Dom	40 Watt	0.054	0.050	100%	60%	2,000	0	7%	2.50	36.21	27.46
13.	Incandescent	Circular Fluorescent	Dom	60 Watt	0.060	0.022	15%	60%	2,000	75	63%	3.50	762.05	578.05
14.	Magnetic ballast	Electronic ballast	Dom	40 Watt	0.054	0.042	100%	60%	2,000	250	22%	6.00	36.21	27.46
15.	Magnetic ballast	Low loss ballast	Dom	40 Watt	0.054	0.045	100%	60%	2,000	120	17%	15.00	471.57	187.25
16.	Ceiling fan	Efficient fan motor	Dom	70 Watt	0.070	0.060	65%	70%	4,000	125	15%	20.00	977.86	741.75
17.	Conventional fan regulator	Electronic Speed Control	Dom	70 Watt	0.070	0.063	65%	70%	4,000	450	10%	4.00	977.86	741.75
18.	Room AC EER 6.0	Room AC EER 9.0	Dom	1 ton	2.000	1.340	65%	40%	1,200	2,000	33%	15.00	202.41	153.54
19.	Std. eff. room cooler	High eff. room cooler	Dom	230 Watt	0.230	0.184	65%	40%	1,200	500	20%	20.00	119.74	90.83
20.	Incandescent lamps	Compact Fluorescent	Ind	60 Watt	0.060	0.016	15%	90%	3,750	300	73%	2.67	17.18	22.42
21.	Incandescent lamps	TLD Fluorescent	Ind	60 Watt	0.060	0.032	50%	90%	3,750	115	47%	1.33	17.18	22.42
22.	TL Fluorescent	TLD Fluorescent	Ind	40 Watt	0.054	0.050	100%	90%	3,750	0	7%	1.33	383.71	500.69
23.	Incandescent	Circular Fluorescent	Ind	60 Watt	0.060	0.022	15%	90%	3,750	75	63%	1.87	17.18	22.42
24.	Magnetic ballast	Electronic ballast	Ind	40 Watt	0.054	0.042	100%	90%	3,750	250	22%	4.50	383.71	500.69
25.	Magnetic ballast	Low loss ballast	Ind	40 Watt	0.054	0.045	100%	90%	3,750	120	17%	8.00	471.57	187.25
26.	HPMV lamp and ballast	HPSV lamp and ballast	Ind	250 Watt	0.285	0.171	50%	90%	4,000	465	40%	6.00	68.72	89.68
27.	Std. eff. Ind. pumps	High eff. Ind. pumps	Ind	4 kW	4.000	3.200	30%	16%	6,000	2,000	20%	15.00	807.5	1,053.69
28.	Constant speed drive	Variable speed drive	Ind	250 hp	117.800	91.295	30%	60%	6,000	1,865,000	23%	10.00	475.34	620.26
29.	Std. eff. motor	High eff. motor	Ind	20 hp	10.100	9.696	55%	60%	6,000	5,584	4%	30.00	3207.11	4,184.88
30.	Reciprocating compressor	Centrifugal compressor	Ind	200 T	210.000	140.000	35%	70%	6,000	400,000	33%	20.00	206.17	269.03
31.	Constant speed motor	Multi-speed motor	Ind	30 hp	14.900	13.559	25%	60%	6,000	20,850	9%	10.00	475.34	620.26
32.	Electric arc furnace	Improvement	Ind	10 tons	2400.000	1680.000	60%	50%	4,000	5,000,000	30%	10.00	160.36	209.24

Table 2.2: Costs and Savings for Energy Efficient Technologies

S. No.	Existing Technology	Proposed Technology	Sector	Avg. tariff in 1993/94 * (paise/kWh)	Savings for EETs kWh/yr	Savings for EETs kW	CSD Rs/peak kW Saved	CSE Rs/kWh Saved	Simple Payback Years	Potential Peak kW Saved	Potential GWh Saved
1	Std eff Agri pumps	High eff. Agri. pumps	Agri	19	2,400	0.80	7813	0.11	4.39	71,472.77	1,038.24
2	Unmetered agri pumps	Metered agri pumps	Agri	19	600	0.20	6250	0.09	3.51	29,780.32	432.60
3	Incandescent lamps	Compact Fluorescent	Com	268	131	0 04	3805	0.31	0.85	8,802.49	3.88
4	Incandescent lamps	TLD Fluorescent	Com	268	85	0.03	2266	0.18	0.51	18,891.18	8.34
5.	TL Fluorescent	TLD Fluorescent	Com	268	11	0.00	0	0.00	0.00	29,708.91	13.11
6	Incandescent	Circular Fluorescent	Com	268	113	0.04	1102	0 09	0.25	7,596.67	3.35
7	Magnetic ballast	Electronic ballast	Com	268	36	0.01	11691	0.94	2.62	93,370.86	41.20
8	Magnetic ballast	Low loss ballast	Com	268	28	0.01	7262	0.59	1.63	72,150.21	31.83
9.	HPMV lamp and ballast	HPSV lamp and ballast	Com	268	456	0.11	2266	0.14	0.38	2,661.12	1.18
10.	Incandescent lamps	Compact Fluorescent	Dom	106	88	0.04	5708	0.46	3.23	50,066.69	63.30
11	Incandescent lamps	TLD Fluorescent	Dom	106	56	0.03	3398	0.27	1.92	107,449.05	135.84
12	TL Fluorescent	TLD Fluorescent	Dom	106	8	0.00	0	0 00	0.00	1,520.82	1.92
13	Incandescent	Circular Fluorescent	Dom	106	76	0.04	1653	0.13	0.94	43,208.24	54.63
14	Magnetic ballast	Electronic ballast	Dom	106	24	0.01	17536	1.41	9.93	4,779.72	6.04
15	Magnetic ballast	Low loss ballast	Dom	106	18	0.01	10893	0 88	6.17	48,100.14	31.83
16	Ceiling fan	Efficient fan motor	Dom	106	42	0.01	8503	0.40	2.81	66,738.95	72.32
17	Conventional fan regulator	Electronic Speed Control	Dom	106	28	0 01	45918	2.16	15.16	44,492.63	48.21
18.	Room AC EER 6 0	Room AC EER 9.0	Dom	106	792	0.66	3788	0.34	2.38	17,366.78	32.93
19	Std eff room cooler	High eff. room cooler	Dom	106	55	0.05	13587	1.22	8.55	6,226.48	11.81
20	Incandescent lamps	Compact Fluorescent	Ind	219	164	0.04	3805	0.25	0.83	1,693.09	2.45
21	Incandescent lamps	TLD Fluorescent	Ind	219	106	0.03	2266	0.15	0.50	3,633.57	5.27
22.	TL Fluorescent	TLD Fluorescent	Ind	219	14	0.00	0	0.00	0.00	24,173.73	35.05
23.	Incandescent	Circular Fluorescent	Ind	219	142	0.04	1102	0.07	0.24	1,461.16	2.12
24.	Magnetic ballast	Electronic ballast	Ind	219	45	0.01	11691	0.75	2.56	75,974.58	110.15
25.	Magnetic ballast	Low loss ballast	Ind	219	34	0.01	7262	0.47	1.59	72,150.21	31.83
26	HPMV lamp and ballast	HPSV lamp and ballast	Ind	219	456	0.11	2266	0.14	0.47	12,369.60	17.94
27	Std. eff. Ind. pumps	High eff. Ind. pumps	Ind	219	4,800	0.80	7813	0.06	0.19	7,752.00	63.22
28	Constant speed drive	Variable speed drive	Ind	219	159,030	26.51	58637	1.58	5.35	19,251.27	41.87
29	Std eff motor	High eff motor	Ind	219	2,424	0.40	11518	0.31	1.05	42,333.85	92.07
30.	Reciprocating compressor	Centrifugal compressor	Ind	219	420,000	70.00	4082	0.13	0.43	16,837.22	31.39
31	Constant speed motor	Multi-speed motor	Ind	219	8,046	1.34	12957	0.35	1.18	6,417.09	13.96
32.	Electric arc furnace	Improvement	Ind	219	2,880,000	720 00	6944	0.23	0.79	14,432.40	37.66

* Source: Annual Report on the Working of State Electricity Boards and Electricity Departments, Planning Commission, Govt. of India, October 1995

The cost of saved demand for the various EETs is given in Table 2.2. This was compared to the average capital cost of building a new peaking power plant, costing Rs 32,000 per kW. These costs were obtained from discussions with senior officials of the Central Electricity Authority and SEBs. The CSD at Rs 45,918.00 for electronic speed controls for fans and at Rs 58,637.00 for variable speed drives exceeded the per kW cost of a new peaking power plant.

2.5 Attributes for assigning weights

2.5.1 Consumer Acceptance

This attribute deals with the acceptability of a particular technology to the consumers.

2.5.2 Availability in India

Many energy efficient technologies are manufactured indigenously, while others are imported. Even though a technology is being imported, it may be readily available in India. This attribute is concerned with the ease of procuring a particular technology locally.

2.5.3 Reliability of Equipment

This attribute compares the reliability of the EET with the old technology.

2.5.4 Sensitivity to Voltage/Frequency Fluctuations

A few EETs are highly sensitive to fluctuations in either the voltage or frequency as compared to the existing technology. This attribute rates the EET in comparison with the existing technology with regard to its sensitivity to fluctuations in the quality of power supplied.

2.5.5 First Cost

The incremental first cost of an EET is a very important decision making criterion for the consumer. Even though the simple payback period may be excellent, a decision might be made to continue with the existing technology if capital is not available to fund the first cost of the EET.

2.5.6 Ease of Installation

The easier it is to install a technology, the wider will be its acceptance amongst consumers. If the installation of an EET requires extensive retrofit, chances are consumers will balk at the option.

2.5.7 Downtime for Installation

This attribute is specially important in the case of EETs aimed primarily at the industrial and commercial sectors. Extended downtime for installation of a technology means prolonged work disruptions and complaints from workers who still have to meet output targets.

2.5.8 Simple Payback

Though economists would argue against the use of this criterion in decision making, the fact remains that it is a popular decision making tool for the consumers. The shorter the payback period, the greater the attractiveness.

2.5.9 Maintenance Requirements

If an EET requires significantly more maintenance than the existing technology, it is negative factor for the EET. Conversely, if the maintenance requirements are lower or same, it is a positive factor.

This attribute has been accorded a comparatively low weightage due to the fact that Indian consumers generally do not take long term maintenance costs into account while making a buying decision.

2.5.10 Local Maintenance Availability

Unless spares for a technology, and expertise for its maintenance are available locally, consumers would be reluctant to install an EET even if it has high reliability. The potential risk of loss in production even on the off hand chance of a breakdown, may be deemed too large by industrial consumers.

2.5.11 Impact on Peak Load

This attribute is important from the point of view of the utility, which is participating in the DSM program to reduce peak load capacity requirements.

The greater the impact of a measure on the peak power requirement, the greater will be the support form the utility for this measure.

2.5.12 Impact on Energy Requirement

This attribute's importance is similar to the one above. The baseload capacity addition requirements of the utility are reduced in proportion to the savings in energy use effected by a particular EET. Hence, EETs having the greatest impact will be preferred.

2.5.13 Utility/Social Acceptance

This attribute deals with the acceptability of the measure to the society, and/or the utility. Since the utility companies in India are state owned as of today, this attribute primarily considers the political acceptability of an EET.

The above 13 attributes were normalised using the values given in Table 2.3.

Table 2.3: Normalisation Matrix for Attributes

S. No.	ATTRIBUTES	Very Low	Low	Medium	High	Very High
1.	Consumer Acceptance	1	2	3	4	5
2.	Availability in India	1	2	3	4	5
3.	Reliability of equipment	1	2	3	4	5
4.	Sensitivity to voltage/frequency fluctuations	5	4	3	2	1
5.	Incremental First Cost	5	4	3	2	1
6.	Ease of installation	1	2	3	4	5
7.	Down time for installation	5	4	3	2	1
8.	Simple payback	5	4	3	2	1
9.	Maintenance requirement	5	4	3	2	1
10.	Local maintenance availability	1	2	3	4	5
11.	Impact on peak demand	1	2	3	4	5
12.	Impact on Energy requirement	1	2	3	4	5
13.	Utility/Social Acceptance	1	2	3	4	5

Table 2.4: Ranking of Energy Efficient Technologies by Weightage Scores

S. No.	Existing Technology	Proposed Technology	Sector	Consumer Acceptance	Availability in India	Reliability of Equipment	Sensitivity to Voltage/Freq. Fluctuations	Incremental First Cost	Ease of Installation	Down time for Installation	Simple Payback	Maintenance Requirement	Local Maint. Availability	Impact on Peak Demand	Impact on Energy Reqmt.	Utility/Social Acceptance	Total
				10	4	9	9	8	6	7	8	5	6	10	8	10	
1	TL Fluorescent	TLD Fluorescent	Com	5	5	5	5	5	5	5	5	5	5	3	2	5	456
2	TL Fluorescent	TLD Fluorescent	Ind	5	5	5	5	5	5	5	5	5	5	2	2	5	446
3	HPMV lamp and ballast	HPSV lamp and ballast	Ind	5	5	5	5	5	4	4	5	5	5	2	2	5	433
4	Ceiling fan	Efficient fan motor	Dom	5	5	5	5	4	4	4	2	5	5	4	3	5	429
5	TL Fluorescent	TLD Fluorescent	Dom	5	5	5	5	5	5	5	5	5	5	1	1	5	428
6	Std eff motor	High eff motor	Ind	5	5	5	4	4	4	4	3	5	5	3	3	5	418
7	Magnetic ballast	Low loss ballast	Ind	4	4	5	4	5	4	4	3	5	5	4	2	5	414
8	Std eff Ind pumps	High eff Ind pumps	Ind	5	5	5	5	4	3	3	5	5	5	1	3	5	410
9	Magnetic ballast	Low loss ballast	Com	4	4	5	4	4	4	4	3	5	5	4	2	5	406
10	Magnetic ballast	Electronic ballast	Ind	4	4	4	3	5	4	4	2	5	5	4	4	5	404
11	Incandescent lamps	TLD Fluorescent	Dom	2	5	5	3	4	3	4	3	5	5	5	4	5	401
12	Incandescent	Circular Fluorescent	Dom	3	5	4	3	4	5	5	4	5	5	3	3	5	401
13	Std. eff Agri pumps	High eff. Agri pumps	Agri	5	5	5	5	1	3	3	1	5	5	4	5	5	400
14	Incandescent	Circular Fluorescent	Ind	4	5	4	3	5	5	5	5	5	5	1	1	5	391
15	Constant speed motor	Multi-speed motor	Ind	5	5	5	5	3	4	4	3	5	5	1	2	5	391
16	Reciprocating compressor	Centrifugal compressor	Ind	4	5	5	5	2	3	3	5	5	5	2	2	5	386
17	Incandescent	Circular Fluorescent	Com	4	5	4	3	4	5	5	5	5	5	1	1	5	383
18	Magnetic ballast	Low loss ballast	Dom	4	4	5	4	4	4	4	1	5	5	3	2	5	380
19	Std eff room cooler	High eff room cooler	Dom	5	5	5	5	2	5	5	1	5	5	1	2	5	380
20	Room AC EER 6 0	Room AC EER 9 0	Dom	5	5	5	5	1	4	4	2	5	5	2	2	5	377
21	Magnetic ballast	Electronic ballast	Com	4	4	4	3	3	4	4	2	5	5	4	2	5	372
22	HPMV lamp and ballast	HPSV lamp and ballast	Com	3	5	5	5	2	4	4	5	5	5	1	1	5	371
23	Incandescent lamps	TLD Fluorescent	Ind	3	5	5	3	5	3	4	5	5	5	1	1	5	371
24	Incandescent lamps	TLD Fluorescent	Com	3	5	5	3	4	3	4	4	5	5	2	1	5	365
25	Incandescent lamps	Compact Fluorescent	Ind	4	5	4	3	5	3	4	4	5	5	1	1	5	364
26	Incandescent lamps	Compact Fluorescent	Dom	3	5	4	3	3	3	4	1	5	5	4	3	5	360
27.	Conventional fan regulator	Electronic Speed Control	Dom	4	5	4	3	2	4	4	1	5	5	3	2	5	350
28	Incandescent lamps	Compact Fluorescent	Com	4	5	4	3	3	3	4	4	5	5	1	1	5	348
29.	Unmetered agri. pumps	Metered agri. pumps	Agri	1	5	5	5	3	4	5	1	5	5	3	4	1	338
30	Electric arc furnace	Improvement	Ind	4	5	5	4	1	2	2	4	3	4	2	2	5	332
31	Magnetic ballast	Electronic ballast	Dom	4	4	4	3	3	4	4	1	5	5	1	1	5	326
32	Constant speed drive	Variable speed drive	Ind	4	4	5	4	1	3	3	1	4	4	2	2	5	322

2.6 Conclusion

Using weights and normalisation values, the total score for each EET was calculated and the EETs ranked in descending order in Table 2.4. From this table it can be seen that the ten most acceptable EETs for GEB are:

1. Replacement of 40 W tubelights with 36 W tubelights in the commercial sector.
2. Replacement of 40 W tubelights with 36 W tubelights in the industrial sector.
3. Replacement of mercury vapour lamps with sodium vapour lamps in the industrial sector.
4. Replacement of standard efficiency ceiling fans with high efficiency fans.
5. Replacement of 40 W tubelights with 36 W tubelights in the domestic sector.
6. Replacement of standard efficiency motors with high efficiency motors in the industrial sector.
7. Replacement of magnetic ballasts with low loss ballasts in the industrial sector.
8. Replacement of standard efficiency pumps with high efficiency pumps in the industrial sector.
9. Replacement of magnetic ballasts with low loss ballasts in the commercial sector.
10. Replacement of magnetic ballasts with electronic ballasts in the industrial sector.

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CHAPTER 3

CHAPTER 3
Technical, economic and market potential of EETs

3.1 Introduction

In the previous chapter, the various energy efficient technologies (EETs) were ranked in order of the score obtained when evaluated against a number of weightage criteria. While these criteria covered both quantitative and qualitative factors, most of them were related to issues of concern to the end-user.

The local electric utility, in this case Gujarat Electricity Board (GEB) is a major stake holder in any Demand Side Management (DSM) plan, and this chapter evaluates the various EETs from the point of view of GEB. GEB's major concern would be the amount of savings in electricity demand which can be achieved through the use of EETs.

The Technical and Economic potentials for energy savings of the various EETs are calculated in this chapter, and the EETs are also ranked in order of their estimated potential for energy savings in order to identify the ten EETs which GEB would stand to benefit most from. Also, the market penetration rates of the EETs are estimated.

3.2 Definition of terms

3.2.1 Technical potential

The 'technical' potential of an EET is defined as the maximum reduction in energy (electricity) demand that may be achieved if the entire potential market adopted that measure. This estimate assumes 100% participation rate and therefore represents an upper bound for the potential savings from an EET.

3.2.2 Economic potential

The 'economic' potential is defined as the maximum possible reduction in energy use and demand using a specified set of economic assumptions. The assumptions include capital and operating costs of the measure, realistic participation rate as a result of favourable economics of the EET, discount rate, etc.

3.2.3 Market potential

The 'market' potential represents the expected energy and demand reduction, taking into account the actual market conditions. Estimating market potential is important in setting priorities and establishing realistic targets.

3.3. Methodology

Calculation of the technical potential is based on the data for the EETs presented in the previous chapter, and the results are tabulated in Table 3.1.

In the case of the economic potential, the payback acceptance methodology was used, as given in the User's Manual for the "COMPASS" software marketed by SRC International. The percentage of consumers adopting a given technology is dependent on the time taken by the new technology to pay back its original cost. The quicker the payback, the greater the number of consumers adopting a particular technology.

The economic potential for energy savings was then obtained as the product of the long run participation rate with the technical potential for a given EET. The rankings of the EETs by the economic potential is given in Table 3.2.

The Lawrence-Lawton diffusion curve was used to calculate the market penetration rate for a given technology. Lawrence and Lawton showed that a diffusion function of the following form describes the time path awareness or the market penetration for many products.

$$S(t) \quad \frac{1+P}{(1+(1/P)e^{Rv})} - P$$

Where,

$S(t)$	=	Cumulative size of the adopting population in percentage in year t
P	=	Initial market parameter
R	=	Diffusion rate parameter
v	=	Current year + Maturity - Base Year
e	=	2.71828

Table 3.1: Technical Potential

S. No.	Existing Technology	Proposed Technology	Sector	Technical Potential GWh Saved
1.	Std. eff. Agri. pumps	High eff. Agri. pumps	Agri	1,038.24
2.	Unmetered agri. pumps	Metered agri. pumps	Agri	432.60
3.	Incandescent lamps	Compact Fluorescent	Com	3.88
4.	Incandescent lamps	TLD Fluorescent	Com	8.34
5.	TL Fluorescent	TLD Fluorescent	Com	13.11
6.	Incandescent	Circular Fluorescent	Com	3.35
7.	Magnetic ballast	Electronic ballast	Com	41.20
8.	Magnetic ballast	Low loss ballast	Com	31.83
9.	HPMV lamp and ballast	HPSV lamp and ballast	Com	1.18
10.	Incandescent lamps	Compact Fluorescent	Dom	63.30
11.	Incandescent lamps	TLD Fluorescent	Dom	135.84
12.	TL Fluorescent	TLD Fluorescent	Dom	1.92
13.	Incandescent	Circular Fluorescent	Dom	54.63
14.	Magnetic ballast	Electronic ballast	Dom	6.04
15.	Magnetic ballast	Low loss ballast	Dom	31.83
16.	Ceiling fan	Efficient fan motor	Dom	72.32
17.	Conventional fan regulator	Electronic Speed Control	Dom	48.21
18.	Room AC EER 6.0	Room AC EER 9.0	Dom	32.93
19.	Std. eff. room cooler	High eff. room cooler	Dom	11.81
20.	Incandescent lamps	Compact Fluorescent	Ind	2.45
21.	Incandescent lamps	TLD Fluorescent	Ind	5.27
22.	TL Fluorescent	TLD Fluorescent	Ind	35.05
23.	Incandescent	Circular Fluorescent	Ind	2.12
24.	Magnetic ballast	Electronic ballast	Ind	110.15
25.	Magnetic ballast	Low loss ballast	Ind	31.83
26.	HPMV lamp and ballast	HPSV lamp and ballast	Ind	17.94
27.	Std. eff. Ind. pumps	High eff. Ind. pumps	Ind	63.22
28.	Constant speed drive	Variable speed drive	Ind	41.87
29.	Std. eff. motor	High eff. motor	Ind	92.07
30.	Reciprocating compressor	Centrifugal compressor	Ind	31.39
31.	Constant speed motor	Multi-speed motor	Ind	13.96
32.	Electric arc furnace	Improvement	Ind	37.66

Table 3.2: **Ranking of Energy Efficient Technologies by Economic Potential**

S. No.	Existing Technology	Proposed Technology	Sector	Simple Payback Years	Long Run Market Share	Economic Potential GWh saved
1.	Incandescent lamps	TLD Fluorescent	Dom	1.92	70.00%	95.09
2.	Std. eff. Agri. pumps	High eff. Agri. pumps	Agri	4.39	8.75%	90.85
3.	Unmetered agri. pumps	Metered agri. pumps	Agri	3.51	18.00%	77.87
4.	Std. eff. motor	High eff. motor	Ind	1.05	78.00%	71.81
5.	Std. eff. Ind. pumps	High eff. Ind. pumps	Ind	0.19	99.00%	62.59
6.	Incandescent	Circular Fluorescent	Dom	0.94	97.00%	52.99
7.	Magnetic ballast	Electronic ballast	Ind	2.56	33.00%	36.35
8.	Ceiling fan	Efficient fan motor	Dom	2.81	50.00%	36.16
9.	TL Fluorescent	TLD Fluorescent	Ind	0.00	100.00%	35.05
10.	Electric arc furnace	Improvement	Ind	0.79	85.00%	32.01
11.	Reciprocating compressor	Centrifugal compressor	Ind	0.43	95.00%	29.82
12.	Incandescent lamps	Compact Fluorescent	Dom	3.23	40.00%	25.32
13.	Magnetic ballast	Low loss ballast	Com	1.63	64.00%	20.37
14.	Room AC EER 6.0	Room AC EER 9.0	Dom	2.38	60.00%	19.76
15.	Magnetic ballast	Low loss ballast	Ind	1.59	62.00%	19.74
16.	HPMV lamp and ballast	HPSV lamp and ballast	Ind	0.47	95.00%	17.04
17.	Magnetic ballast	Electronic ballast	Com	2.62	40.00%	16.48
18.	TL Fluorescent	TLD Fluorescent	Com	0.00	100.00%	13.11
19.	Constant speed motor	Multi-speed motor	Ind	1.18	70.00%	9.77
20.	Incandescent lamps	TLD Fluorescent	Com	0.51	94.26%	7.86
21.	Magnetic ballast	Low loss ballast	Dom	6.17	16.00%	5.09
22.	Incandescent lamps	TLD Fluorescent	Ind	0.50	78.42%	4.13
23.	Incandescent lamps	Compact Fluorescent	Com	0.85	90.00%	3.50
24.	Incandescent	Circular Fluorescent	Com	0.25	98.00%	3.28
25.	Incandescent	Circular Fluorescent	Ind	0.24	97.00%	2.06
26.	Incandescent lamps	Compact Fluorescent	Ind	0.83	82.00%	2.01
27.	TL Fluorescent	TLD Fluorescent	Dom	0.00	100.00%	1.92
28.	Constant speed drive	Variable speed drive	Ind	5.35	3.00%	1.26
29.	HPMV lamp and ballast	HPSV lamp and ballast	Com	0.38	96.00%	1.13
30.	Std. eff. room cooler	High eff. room cooler	Dom	8.55	8.50%	1.00
31.	Conventional fan regulator	Electronic Speed Control	Dom	15.16	1.00%	0.48
32.	Magnetic ballast	Electronic ballast	Dom	9.93	5.80%	0.35

3.3.1. Initial Market Parameter

The initial market parameter "P" is an indication of the initial state of the market. Its value typically ranges from 0.005% to 0.30% and is entered as a percent (i.e. 0.5 to 30). This value is chosen judgementally based on knowledge of local factors and information influencing the market for each product.

3.3.2 Diffusion Rate Parameter

The diffusion rate parameter "R" is a measure of the rate of diffusion of the new product in the marketplace. The specific value of R depends on the nature of the product, the communication channels employed, and the social system attributes. Lawrence and Lawton recommend the value of 0.5 for products for the residential sector and 0.66 for products for the commercial sector.

3.3.3 Market Maturity

A utility program may involve different kinds of measures at different stages of the product life cycle curve. The maturity parameter used in the diffusion function attempts to capture this variation. It is defined as the number of years a particular measure has been in the market before the base year. Products that have been on the market place for a number of years e.g. TLD tubelights, are classified as mature products and the parameter would therefore take relatively large values.

The cumulative annual market share is then calculated as the product of the long-run market share and the share obtained from the market diffusion process.

The percentage of the market adopting a given technology for the years 1997, 2002, 2007 and 2012 are given in Table 3.3. Table 3.3 also gives the values of the Initial Market Parameter, Diffusion Rate Parameter and Maturity for the different EETs.

Both the technical potential, as well as the economic potential as calculated in this chapter have not taken into account any incentives or rebates for the purchase/installation of EETs, which may be offered by the utility. An underlying assumption of the market diffusion rate calculation is that basic information is available in the market place for people to make an informed judgement regarding the payback of a particular energy efficient technology.

Table 3.3: Market Penetration Values for the Energy Efficient Technologies

S. No.	Existing Technology	Proposed Technology	Sector	Initial Market Parameter P (%)	Diffusion Rate Parameter R	Maturity	Long Run Market Share	Adopting Percentage of Population in Year 1997	2002	2007	2012
1.	Std. eff. Agri. pumps	High eff. Agri. pumps	Agri	0.50	0.33	5.00	8.75%	5.11%	7.85%	8.57%	8.71%
2	Unmetered agri. pumps	Metered agri. pumps	Agri	0.50	0.33	5.00	18.00%	10.51%	16.15%	17.62%	17.93%
3	HPMV lamp and ballast	HPSV lamp and ballast	Com	10.00	0.33	5.00	96.00%	76.10%	92.12%	95.25%	95.86%
4.	Incandescent	Circular Fluorescent	Com	0.50	0.33	3.00	98.00%	35.33%	79.64%	94.08%	97.23%
5.	Incandescent lamps	TLD Fluorescent	Com	11.00	0.33	5.00	94.26%	74.85%	90.48%	93.53%	94.12%
6.	Incandescent lamps	Compact Fluorescent	Com	2.50	0.33	2.50	90.00%	43.02%	79.74%	87.98%	89.61%
7	Magnetic ballast	Low loss ballast	Com	5.00	0.33	3.50	64.00%	41.24%	59.41%	63.11%	63.83%
8	Magnetic ballast	Electronic ballast	Com	0.50	0.33	2.00	40.00%	9.50%	30.06%	37.80%	39.56%
9	TL Fluorescent	TLD Fluorescent	Com	11.00	0.33	5.00	100.00%	79.41%	95.99%	99.23%	99.85%
10.	Ceiling fan	Efficient fan motor	Dom	10.00	0.25	5.00	50.00%	34.68%	45.52%	48.71%	49.63%
11	Conventional fan regulator	Electronic Speed Control	Dom	5.00	0.25	3.00	1.00%	0.48%	0.84%	0.95%	0.99%
12.	Incandescent	Circular Fluorescent	Dom	0.50	0.25	3.00	97.00%	26.32%	66.01%	86.53%	93.84%
13.	Incandescent lamps	TLD Fluorescent	Dom	11.00	0.25	5.00	70.00%	48.68%	63.78%	68.21%	69.49%
14.	Incandescent lamps	Compact Fluorescent	Dom	2.50	0.25	2.50	40.00%	15.31%	31.91%	37.58%	39.30%
15.	Magnetic-ballast	Low loss ballast	Dom	5.00	0.25	3.50	16.00%	8.61%	13.76%	15.35%	15.81%
16.	Magnetic ballast	Electronic ballast	Dom	0.50	0.25	2.00	5.80%	1.03%	3.56%	5.01%	5.56%
17	Room AC EER 6.0	Room AC EER 9.0	Dom	5.00	0.25	2.50	60.00%	25.19%	49.29%	56.86%	59.10%
18.	Std. eff. room cooler	High eff. room cooler	Dom	10.00	0.25	3.00	8.50%	4.28%	7.25%	8.14%	8.40%
19.	TL Fluorescent	TLD Fluorescent	Dom	11.00	0.25	5.00	100.00%	69.54%	91.11%	97.44%	99.27%
20.	Constant speed drive	Variable speed drive	Ind	3.00	0.33	4.00	3.00%	2.02%	2.80%	2.96%	2.99%
21	Constant speed motor	Multi-speed motor	Ind	7.00	0.33	5.00	70.00%	55.05%	67.06%	69.43%	69.89%
22.	Electric arc furnace	Improvement	Ind	1.50	0.33	3.50	85.00%	48.11%	76.76%	83.37%	84.68%
23.	HPMV lamp and ballast	HPSV lamp and ballast	Ind	10.00	0.33	5.00	95.00%	75.31%	91.16%	94.26%	94.86%
24.	Incandescent	Circular Fluorescent	Ind	0.50	0.33	3.00	97.00%	34.97%	78.83%	93.12%	96.24%
25	Incandescent lamps	TLD Fluorescent	Ind	11.00	0.33	5.00	78.42%	62.27%	75.28%	77.81%	78.30%
26.	Incandescent lamps	Compact Fluorescent	Ind	2.50	0.33	2.50	82.00%	39.19%	72.65%	80.16%	81.64%
27.	Magnetic ballast	Low loss ballast	Ind	5.00	0.33	3.50	62.00%	39.95%	57.55%	61.14%	61.83%
28.	Magnetic ballast	Electronic ballast	Ind	0.50	0.33	2.00	33.00%	7.84%	24.80%	31.18%	32.64%
29.	Reciprocating compressor	Centrifugal compressor	Ind	8.00	0.33	5.00	95.00%	74.96%	91.08%	94.24%	94.85%
30.	Std. eff. Ind. pumps	High eff. Ind pumps	Ind	16.00	0.33	5.00	99.00%	79.04%	95.13%	98.26%	98.86%
31	Std eff motor	High eff. motor	Ind	3.50	0.33	5.00	78.00%	59.74%	74.34%	77.29%	77.86%
32	TL Fluorescent	TLD Fluorescent	Ind	11.00	0.33	5.00	100.00%	79.41%	95.99%	99.23%	99.85%

While offering rebates or incentives will increase the rate of penetration, an information dissemination program is necessary to ensure the rates of diffusion as calculated are actually realised.

3.4 Conclusions

From Table 3.2, it can be seen that the ten most acceptable EETs from the point of view of potential energy savings for GEB are:

1. Replacement of incandescent lamps with 36 W tubelights in the domestic sector.
2. Replacement of standard efficiency pumps by high efficiency pumps in the agriculture sector.
3. Metering of unmetered agricultural pumps.
4. Replacement of standard efficiency motors with high efficiency motors in the industrial sector.
5. Replacement of standard efficiency pumps with high efficiency pumps in the industrial sector.
6. Replacement of incandescent lamps with circular fluorescent lamps in the domestic sector.
7. Replacement of magnetic ballasts with electronic ballasts in the industrial sector.
8. Replacement of standard efficiency ceiling fans with high efficiency fans.
9. Replacement of 40 W tubelights with 36 W tubelights in the industrial sector.
10. Undertaking efficiency improvement measures in the electric arc furnaces.

CHAPTER 4

CHAPTER 4

Electricity pricing options for demand management

4.1 Background

Energy prices in India have been administered with the goal of achieving certain social objectives, such as subsidising agricultural and low income residential customers. The prices therefore do not reflect the true cost of power generation, transmission and distribution. The pricing of energy below costs sends an inaccurate signal of the value of energy to the consumer.

In the last two chapters a discussion has been presented on the different technologies that could replace the existing ones and the likely benefits and costs associated with each option. A properly devised pricing policy can defer investment in new generation capacities by creating incentives to shift load from peak to off-peak times as well as inducing users to invest in energy efficient measures.

4.2 Current pricing practice in Gujarat Electricity Board

In GEB four sectors, domestic, commercial, industry and agriculture, account for the bulk of electricity consumption. Present tariff structure subsidises agriculture and domestic sectors at the expense of industrial and commercial sectors. Gujarat is an industrialised state and also has a highly commercialised agriculture sector. These two sectors between them account for almost 85% of electricity consumption. Moreover, as discussed in a later section of this chapter, the tariff structure in the agriculture sector completely distorts the incentive for energy conservation. Thus the first step towards correcting price distortion would involving setting tariffs for each sector so that it reflects the cost of generation, transmission and distribution. From this perspective only, agriculture and domestic sectors can be targeted by a 'fair' tariff since the two other sectors are already paying a tariff which is above the unit cost of generation, transmission and distribution. The tariff schedule for domestic, commercial, agriculture, industrial LT and industrial HT consumers is given in Tables 4.1 to 4.5 respectively. These have been taken from the Council of Power Utilities' (NCPU) publication "Summary of Tariff Schedules of Electric Power Supply Utilities". NCPU had received these tariffs from GEB vide their letter no. 2969 dated 30/5/94.

Table 4.1: Tariff schedule for domestic consumers

Applicable to	Fixed charges	Energy charges		Min. charges
		kWh/Month	Paise/kWh	
Lights, Fans & Small Electrical Appliances such as Refrigerators, Cookers, Heaters, etc. for domestic purposes	1. For single phase supply (i) Rs 3/month installation for consumption upto 100 units / month / installation and Rs 4 per month / installation for consumption above 100 units/month (ii) For 3 phase supply (aggregate load for motors not exceeding 10 kW Rs 10 per month / installation	(i) For consumption upto 100 units		Fixed charges as the minimum bill
		1-10 Units 36	36	
		11-50 Units 68	68	
		51-100 Units 88	88	
		(ii) Total consumption from 101 to 250		
		1-50 Units	68	
		51-100 Units	88	
		101-200 Units	103	
		201-250 Units	128	
		(iii) Total consumption above 250		
		1-50 Units	78	
		51-100 Units	98	
		101-200 Units	137	
		Above 200	187	

Table 4.2: Tariff schedule for commercial consumers

Applicable to	Fixed charges	Energy charges		Min. charges
		kWh/Month	Paise/kWh	
(i) Commercial Premises such as Shops, Workshops, Restaurants, Showrooms, offices, etc.	(i) Single phase supply Rs 30/month/installation for consumption upto 50 kWh/month Rs 35/month/installation for consumption above 50 kWh/month. (ii) For three phase loads (loads upto 10 kW) Rs 50/month/installation	1-50	150	Payment of Fixed charges will be the minimum charges.
		51-150	180	
		Above 150	220	
(ii) Educational Institutions, R&D laboratories for motive power services		All Units	140	

Table 4.3: Tariff schedule for agriculture consumers

Applicable to	Fixed charges	Energy charges		Min. charges
		kWh/month	Paise/kWh	
(i) Motive power service used for irrigation purpose only (flat rate)	The rates including electricity duty at 5% will be as under (i) Upto 7.5 HP Rs 350/HP/annum (ii) Above 7.5 HP Rs 600/HP/annum		- -	
(ii) -do- (Metered supply)		All units	50	

Table 4.4: Tariff schedule for industrial LT consumers

Applicable to	Fixed charges	Energy charges		Min. charges
	Rs/kVA/month	kWh/month	Paise/kWh	
LT Industrial Motive power service not exceeding 125 BHP (i) Installation having contracted load not exceeding 10 BHP	Rs 15/BHP/month	All units	110	(i) Rs 70 / BHP /month upto contracted load of 75 BHP
(ii) Installation having contracted load exceeding 10 BHP				(ii) Rs 110 / BHP/month for the load exceeding 75 BHP
(a) 1-10 BHP	Rs 15/BHP/month	All units	133	
(b) 11-50 BHP	Rs 23/BHP/month	-do-	133	
(b) 51-75 BHP	Rs 35/BHP/month	-do-	133	
(c) 76-100 BHP	Rs 55/BHP/month	-do-	133	
(e) Above 100 BHP	Rs 85/BHP/month	-do-	133	

Table 4.5: Tariff schedule for industrial HT consumers

Category of HT Loads	Fixed/Demand charges Rs/kVA/month	Energy charges kWh/month	Energy charges Paise/kWh	Min. charges
Industrial loads at high tension 3.3 kV and above, 3 phase 50 C/s.				
HT Consumers with contract demand 100 kVA and above for regular power supply	<u>Billing demand upto contract demand</u> 1-1000 kVA- Rs 55/kVA/month	All units	133	Demand charges and the additional charges based on the kVA of the billing demand
	Above 1000 kVA- Rs 100/kVA/month	-do-	-do-	
	<u>Excess contract demand</u> upto 10% Excess- Rs 200/kVA/month	-do-	-do-	
	Above 10% Rs 300/kVA/month	-do-	-do-	

The average unit cost of power supply was 171.60 paise/kWh in 1994-95 for GEB (Planning Commission). This, compared to the tariffs for the various consumer categories, is higher for all except for the maximum slabs in the domestic and commercial tariffs. Thus, the tariffs in general do not signal the correct value of energy conservation, and promote excessive consumption of electricity.

4.3 Pricing options

In this section we discuss some of the pricing options for promoting energy conservation. Options for shifting demand from peak to off peak times are also discussed in brief.

4.3.1 Time of day rates

Time of day rates make electricity more expensive when it costs more to generate additional electricity - during the utility's peak hours and/or season. TOD rates have been successfully used by European and American utilities for several decades and have recently been used in Korea and Taiwan. TOD rates are assumed to be applicable to all large industrial and irrigation customers and the larger commercial customers. At present, the system load curve of Gujarat Electricity Board is almost flat, and TOD

rates will only have a minor impact. But even this minor impact can result in a peak capacity saving of over 100 MW, if the full potential of load shifting is realised, as discussed in Chapter 1

It must be added that GEB is among the few SEBs to have experimented with the TOD rate system. But this is applicable only to industrial customers with connected load over 500 kVA. GEB introduced the TOD tariff for HT industries in April 1984 with a penalty charge of 6 paise/unit during the evening and morning peak hours and revised it to 10 paise/unit in May 1987. At present this penalty is 15 paise/unit. This charge is levied on HT consumers whose contract demand is more than 500 kVA.

4.3.2 Seasonal tariffs

It may be thought of as a variation of Time of Use tariff. Under this pricing scheme tariff rate changes across seasons. Seasonal rates offer an economical way of managing demand. Since the peak months are fairly stable the tariffs can be adjusted to reflect seasonal demand variations. Though this pricing system is not as sophisticated as time of use tariff but nevertheless has several advantages over TOD. It dispenses with the need for expensive meters needed under TOD system and covers a much larger group of consumers under its scope. As the term suggests the tariff is structured so that it costs more to use energy at certain times of the year than at others. The advantage of seasonal tariffs is its relative administrative ease. No significant capital expenditures are required. Only consumers billing frequency has to be synchronised with the time when the seasonal rates come into effect. The demand and energy savings would depend on a large number of factors some of which are:

- The sector to which seasonal tariffs are applicable.
- The span of period over which seasonal rates apply.
- The nature of products manufactured.
- Extent of tariff differential.

Thus seasonal tariffs may have altogether different impact in the agriculture sector than in the industries. Span over which seasonal tariff rates apply would also make a difference. Some industries may find it profitable to work more intensively during off peak season and increase inventories. However as the span over which seasonal rates apply increases, cost inventories would go up and stocking in inventories may become

less profitable. Of course the opportunity for storage can apply mainly to non-perishable commodities and may not be applicable to perishable commodities and would be relatively less profitable for low value-added-high volume good. Lastly, it is to be expected that load shift across seasons may be more depending on the seasonal tariff differential since such differential would impinge on the profitability of altering production schedule.

4.3.3 Curtailable/interruptible rates

Curtailable/interruptible (C/I) rates credit customers for reducing demand, upon notice from the utility, to a predetermined level. Credits can be based upon the probability of interruption or curtailment (priority level), the number of times the service can be interrupted, or the actual interruptions experienced. Instead of credits, some US utilities offer participating customers lower rates and then charge penalties if the customers fail to reduce consumption when contacted by the utility. Owing to the nature of the service, C/I rates are primarily aimed at industrial and commercial customers. It has been estimated that all India peak demand can be reduced by 20% during both summer and winter peak periods. (Rubeinstein *et al*). However no separate estimate of potential peak demand savings for state of Gujarat is available. The crucial element for success is the reliability of communication system and ability to respond on part of consumers to communication signals. To assess the feasibility and effectiveness of a curtailable/interruptible rates scheme, the GEB may consider devising such a scheme and getting feedback from industry representatives. Following this it may consider carrying out experiments with such a pricing scheme for one or two sectors as a pilot project.

4.3.4 Spot pricing

The rationale for time of use pricing is based on implicit assumption of perfect knowledge of future demand and supply, so that structure of tariffs can be chosen to match supply and demand. In practice however both supply and demand are stochastic and thus may not equalise. So if tariffs are pre-determined, excess demand needs to be rationed through load shedding or voltage reductions once supply falls short of demand while capacity will be slack in idle periods. Ideally a more efficient allocation of services could be achieved by continuously adjusting the level and structure of tariffs so to equate demand with supply over time. This approach is known as spot

pricing. Spot pricing is essentially continuous time peak load pricing defined in the face of stochastic demand and supply. Since an effective spot pricing scheme would require a very short time lag for response on part of the target consumers, we may rule out the feasibility of spot pricing as remote for some time to come.

4.3.5 Pro-rata tariff structure for agriculture

Electricity to the agriculture sector is heavily subsidised. Moreover the electricity tariff to the agriculture sector is based on the rated capacity of the irrigation pump and not on actual energy consumption. Hence there is no incentive to save energy (or water). However a case study conducted in Mehsana district of Gujarat showed that under a pro-rata tariff structure, impact on energy consumed will occur only at tariff rates above 70 paise per kWh (at 1993/94 price levels) (TERI 1994). However the biggest obstacle in altering tariff rate and structure is the strong farmer lobby in the agriculture sector (TERI 1994).

4.3.6 Other options

Inverted tariff structure with variations is already in place for the major sectors. However in some sectors there is both scope and justification to create steeper tariff rates, for example the highest consumption slab within the domestic sector still has an element of subsidy as can be seen from Table 4.1. Moreover, as pointed out elsewhere in the report, a portion of tariff represents fixed charges that do not vary with actual energy consumption. Hence the energy conservation incentive is actually smaller than that indicated by the average tariff. GEB may also consider giving discounts on energy rates for buildings that meet pre-specified energy conservation standards.

4.4 Conclusions

Pricing reform is an important element in any DSM strategy. This will involve changes in both rate level and structure. The most important reform needed is to make the power tariffs for different sectors reflect the actual cost of generation and supply. Only this measure can send the correct signals to consumers about the favourable cost/benefit ratios of most energy efficient technologies. Among the other pricing options, GEB should consider incorporating a seasonal element in its tariff structure. In the longer run it should explore the potential of using curtailable/interruptible rates for managing peak demand.

CHAPTER 5

CHAPTER 5
Assessment of the potential role of cogeneration as a DSM option

5.1 Calculation of cogeneration potential

According to the information supplied by GEB the current installed capacity of captive power plants that also include cogenerator is approximately 1548 MW of which approximately 1000 MW is in operation. TERI carried out the cogeneration potential for the State of Gujarat based on the questionnaire survey. About 175 questionnaires were sent to the energy intensive industries based on the heat to power ratios generally applicable for cogeneration. Responses received from the various industries were only twenty-two. Detailed analysis in each of these plants based on the information available in the questionnaire was carried out. Process consideration and existing captive power capacities were used for doing the calculations. The calculations were carried out by using a spreadsheet computer software program. Of the twenty-two industries, which represented a various mix of the State's industrial profile only eighteen were economically viable. They made various assumptions to calculate the potential for cogeneration in each of these sites.

5.2 Techno-economic assumptions

Only continuous process industries were considered for estimating the cogeneration potential. It was assumed that GEB would provide back up power in case of failure of the cogeneration plant. Cogeneration potential was exploited to the extent it was beneficial in the industries. In certain industries importing some power was necessary as it was not possible to cogenerate surplus power that the industries could feed to the grid. Thermal match and the electrical match options were examined for the techno-economic analysis for topping cycle mode of cogeneration. The captive power plants were considered shut down when the cogeneration plant operated.

A pressure of 100 kg/cm sqrs gauge was assumed for all the boiler using topping cycle cogeneration system. A pressure of 27 kg/cm sqrs gauge was assumed to be the boiler pressure for waste heat recovery boilers. No supplementary firing was assumed in the waste heat recovery boilers. ASME methodology was used for calculating the steam rates for the various sizes of turbines used for determining the cogeneration

potential. The steam rate table for various extraction pressures based as ASME methodology is given in Annexure 5.1. This table has been taken from the Electrical Engineer's Handbook published by McGraw Hills.

No financial incentives were considered for calculating the economic viability. Four years or less simple pay back period was assumed to be acceptable for an economically viable investment. The discount factor adopted for calculating the NPV was 16%. The capital costs are assumed at Rs. 3.5 crores per MW, which is a much higher figure than the normal cogeneration plants because it will involve process modifications and a shutdown. The purchase price of cogenerated power was assumed to be Rs. 2.25 per kWh.

5.3 Economic analysis

Table 5.1 describes the economic payback analysis methodology adopted for the calculations. The industries that presented economically viable cases for cogeneration represented a vast range covering most sectors.

TABLE 5.1: Economic payback analysis

I.	Annual savings	=	present costs without cogeneration
		-	future costs with cogeneration
		=	revenues
		-	operating costs
		=	[sale of electric power or savings of cost avoided or displaced by power generated
		+	heat the combustion turbine exhaust displaced (drying, hot water, steam)]
		-	[combustion turbine fuel costs
		+	operating costs
		+	maintenance and overhaul costs]
II.	Payback period	=	project total installed cost
		÷	annual savings

All the twenty-two questionnaires were analysed for estimating the cogeneration potential of which only eighteen of them were economically attractive. The results of the detail analysis are shown in Table 5.2. The cogeneration potential in the sugar industries that supplied information in the questionnaires is given in Table 5.3. The total GEB supply to these industries was around 67 MW. The total captive power installed in these sectors amounted to 77 MW. The total power demand of these industries was around 133 MW. The maximum cogeneration potential was around 318 MW and export potential in these eighteen industries was 250 MW. The minimum cogeneration potential was around 194 MW and the minimum export potential was around 158 MW. The fluctuation in the cogeneration potential is due to the presence of sugar industries in the area assumed to operate at different loads during the cane crushing seasonal and in the off season. During the off-seasonal operation the cogeneration plants in the sugar industry essentially would operate as a power plant in condensing mode. In determining the cogeneration potential in the State exports of less than one MW were not considered though it was economical.

Table 5.4 contains the details of the financial analysis for the eighteen industries. Among the eighteen industries, all of them operated around 8000 hr. or more per year except the sugar plants. The simple pay back period for these cogeneration projects in these industries was 1.4 to 3.9 years. The total energy cost for each of these industries was calculated based on the information supplied in the questionnaire. The electricity cost was taken from their copy of the GEB bill that they attached with the questionnaire. The internal rate of return for these projects varied between 25% and as high as 70%.

5.4 Cogeneration potential

The State wide projection was carried out based on the HT industry list provided by GEB. The electricity consumption for a month for these industries and the connected demand was provided by the GEB. This data was used to segregate according to their nature of products manufactured and their capacities estimated based on the standard specific energy consumption figures. The cogeneration potential was estimated on the total production of the product in the State. These figures estimate the total technical cogeneration potential in the State.

Table: 5.2 Cogeneration Potential in Selected Industries

	GEB demand MW	Captive plant MW	Total demand	MAXIMUM Cogen potential (MW)	MINIMUM Cogen potential (MW)	MAXIMUM EXPORT TO GEB (MW)	MINIMUM EXPORT TO GEB (MW)
Core Healthcare Limited	17.00	5.00	22.00	22.00	22.00	5.00	5.00
Gujarat Ambuja Cements Limited	34.00	12.60	46.60	8.14	8.14	0.00	0.00
Polychem Limited	1.10	0.95	1.10	1.25	1.25	0.15	0.15
Gujarat Steel Tubes	2.50	4.23	2.50	3.00	3.00	0.50	0.50
Valsad SKY Mandali Ltd.	0.26	4.00	4.26	25.62	15.80	25.36	15.54
Sri Ukai Pradesh Sahakari Khand Udyog Mandli Ltd.	0.44	3.00	3.44	25.62	15.80	25.19	15.37
Sri Madhi Vibhag Khand Udyog Sahakari Mandli Ltd.	0.30	7.00	7.30	51.25	31.61	50.95	31.31
Shree Chalthan Vibhag Khand Udyog Sahakari Mandli Ltd.	0.42	8.00	8.42	51.25	31.61	50.83	31.19
Shree Madhuva Pradesh Sahakari Khand Udyog Mandli Ltd.	0.49	6 00	6.49	35.87	22.12	35.38	21.63
Shree Sayan Vibhag Sahakari Khand Udyog Mandli Ltd.	0.44	8.00	8.44	51.25	31.61	50.81	31.17
Dcw Limited	0.70	3.45	4.15	10.82	10.82	10.12	10.12
Gujarat Heavy Chemicals Limited	1.50	9.00	10.50	22.38	22.38	20.88	20.88
Camphor & Allied Products Ltd	0.09	0.00	0.09	0.10	0.10	0.01	0.01
The Ahmedabad Kaiser-I-Hind Mills Company Limited	1.80	1.60	1.80	2.00	2.00	0.20	0.20
Glaxo India Limited	1.50	2.70	1.50	2.75	2.75	1.25	1.25
Anil Starch Products Ltd.	4 30	1.00	4.30	4.50	4.50	0.20	0.20
Rosemount Pharma India Ltd.	0.48	0.00	0.48	0.50	0.50	0.02	0.02
TOTAL	67.32	76.53	133.37	318.30	225.99	276.85	184.54

Table: 5.3 Cogeneration Potential in selected Sugar Industries

	GEB Supply MW	Captive plant MW	Total demand	Maximum Cogen potential (MW)	Minimum Cogen potential (MW)	Maximum EXPORT TO GEB (MW)	Minimum EXPORT TO GEB (MW)
Valsad SKY Mandali Ltd.	0.26	4	4.26	25.62	15.8	25.36	15.54
Sri Ukai Pradesh Sahakari Khand Udyog Mandli Ltd.	0.435	3	3.435	25.62	15.8	25.185	15.365
Sri Madhi Vibhag Khand Udyog Sahakari Mandli Ltd.	0.3	7	7.3	51.25	31.61	50.95	31.31
Shree Chalthan Vibhag Khand Udyog Sahakari Mandli Ltd.	0.42	8	8.42	51.25	31.61	50.83	31.19
Shree Madhuva Pradesh Sahakari Khand Udyog Mandli Ltd.	0.49	6	6.49	35.87	22.12	35.38	21.63
Shree Sayan Vibhag Sahakari Khand Udyog Mandli Ltd.	0.44	8	8.44	51.25	31.61	50.81	31.17
TOTAL	2.345	36	38.345	240.86	148.55	238.515	146.205

Table: 5.4 Financial Analysis of Cogeneration projects at selected sites.

	Annual optg. hours	Electricity cost (Rs/annum)	Current Energy Costs	Cost of new eqpmt. (Rs)	Annual benefits (Rs)	Present value (Rs)	Internal Rate of Return	Simple payback (years)
Core Healthcare Limited	8500	390150000	457554169	770000000	315098549	946697554	41%	2.44
Gujarat Ambuja Cements Limited	7920	303600000	1314875370	284994953	168423875	615140864	59%	1.69
Polychem Limited	7920	23522400	23672515	33750000	16694321	56231012	49%	2.02
Gujarat Steel Tubes	6000	40500000	45627025	81000000	30931043	88263129	38%	2.62
Valsad SKY Mandali Ltd.	3935	2762370	2762370	896838602	246754802	488044274	27%	3.63
Sri Ukai Pradesh Sahakari Khand Udyog Mandli Ltd.	4000	4698000	4698000	896838602	255249486	531461196	28%	3.51
Sri Madhi Vibhag Khand Udyog Sahakari Mandli Ltd.	4300	3483000	3483000	1793677205	480231950	908225534	27%	3.74
Shree Chalthan Vibhag Khand Udyog Sahakari Mandli Ltd.	4650	5273100	5273100	1793677205	463198676	821167286	26%	3.87
Shree Madhuva Pradesh Sahakari Khand Udyog Mandli Ltd.	4800	6350400	6350400	1255574043	318065291	543262470	25%	3.95
Shree Sayan Vibhag Sahakari Khand Udyog Mandli Ltd.	4320	5132160	5132160	1793677205	470394288	857944561	26%	3.81
Dew Limited	8000	15120000	95120000	378780679	121283669	293354221	32%	3.12
Gujarat Heavy Chemicals Limited	8256	33436800	265636800	783286769	240405271	467958161	30%	3.26
Camphor & Allied Products Ltd	5784	1405512	4442112	2700000	1946513	7621177	72%	1.39
The Ahmedabad Kaiser-I-Hind Mills Company Limited	7416	36041760	40097385	54000000	25173145	82109976	47%	2.15
Glaxo India Limited	8600	34830000	41555200	96250000	25654980	48150252	26%	3.75
Anil Starch Products Ltd.	8760	101703600	134555697	157500000	87398094	310921890	55%	1.80
Rosemount Pharma India Ltd.	8760	11352960	13907960	13500000	9639392	37629676	71%	1.40

5.4.1 Cogeneration potential in the pulp and paper sector

The total HT connected load in the pulp and paper sector as on May 1995 was 54 MVA and the total power consumption in the sector was 19653 MWh. Based on detailed calculations the cogeneration potential amounts to about 2.99 MW per ton of paper produced. The technical cogeneration potential in the State is around 58.30 MW and an export possibility of 16.77 MW to the grid.

5.4.2 Cogeneration potential in the cement sector

The cement sector has a connected load of 130 MVA and consumes approximately 50055 MWh of power per month. Based on the detailed calculations approximately 4.5 MW cogeneration potential exists for a one million tons per annum capacity plant. The cogeneration potential in the sector is 29.5 MW with no exports to the grid.

5.4.3 Cogeneration potential in the sugar sector

The sugar sector has one of the highest cogeneration potential in the State at about 274 MW and an export potential of 269 MW to the State grid. This sector currently has a connected load of 5700 kVA and consumes about 716 MWh per month.

5.5 Estimated cogeneration potential in Gujarat in selected HT industries

Among the different industrial sectors, as per the list provided by GEB on the major sectors such as pulp and paper, cement and sugar were considered to make State level projections. This was done based on the production capacities and the specific energy consumption in each of these sectors. Table 5.5 indicates the cogeneration potential in Gujarat in selected HT industries. Although cogeneration potential in other industrial sectors exists, it was not considered as data was not available.

TABLE 5.5: Estimated cogeneration potential in some industrial sectors

	Total Cogeneration (MW)	Exportable Power (MW)
Pulp and paper	58	17
Cement	30	0
Sugar	274	269
Chemical & pharmaceuticals	54	6
Total (MW)	416	292

There is no separate data available on the cogeneration capacity installed in Gujarat. However, GEB has given a list which has the total captive power installed in the State which is about 1548 MW. Approximately 1000 MW of this capacity is in operation. Most of the installed capacity is in the chemicals and the fertiliser sector which amounts to 940 MW. Although it will be difficult to estimate the portion of power generated through cogeneration from this list of captive power plants a fair estimate could made based on the manufacturing process. This is estimated to be approximately 421 MW. The industrial sectors considered for estimating the existing cogeneration in the State were fertilisers, petrochemicals, chemicals, petroleum refineries and the sugar mills.

5.6 Government of India's cogeneration policy

GOI's policy on cogeneration (Annexure 5.2) has been derived on the basis of efficiency. This is applicable to most continuos process industries running on conventional fossil fuels. However, it is not advisable to apply this concept to the sugar, ricemills and other agro based industries whose main source of fuel is agro wastes generated in the manufacturing processes. With regard to the amount of power fed to the grid from the cogeneration the policy mentions that the minimum power must be 5 MW for at least 250 days. This aspect however restricts industries to exploit the available cogeneration potential up to 4 MW and below. It is recommended that if energy efficiency norms laid down in the policy for defining the cogeneration facility is met with then the industry irrespective of the quantum of power and the duration should be allowed to cogenerated. However, other aspects related to safety and operability should be taken into consideration. The policy is silent on banking, wheeling and third party sales by the cogenerator. The policy also does not state any aspects related back-up power required by the cogenerator. The tariff of the cogenerated power is not defined clearly and just indicates a range. It would be advisable to lay down clear norms for cogeneration in which the benefits are shared between the cogenerator and the SEB.

5.7 Current cogeneration policy of GEB

GEB still has to come up with a formal cogeneration policy for the State. As per the information supplied by GEB the current operational capacity of captive power plants which also include cogenerator is approximately 952 MW. There is no restriction on installation of captive power plants, subject to environment and other clearances. However, the GEB is considering the following aspects for cogeneration with regard to purchase of power:

- For short term purchase of power between one to three years GEB is considering purchase 10 percent of the installed capacity subject to a minimum of 5 MW.
- For medium term purchase of power between three to ten years GEB is considering purchase 10 percent of the installed capacity subject to a minimum of 20 MW.
- For long term purchase of power for more than ten years GEB is considering assured supply from cogenerators or IPPs greater than 20 MW power.
- GEB has categorically stated that no payments will be made for off-peak flow of power to the grid.
- GEB will not make any payment for inadvertent flow of power to the grid.
- The purchase price of power would be negotiated on a case to case basis.

The purchase of cogenerated power at present is optional, this prevents the cogenerator to plan for surplus generation under the power maximisation mode and hence is an impediment to cogeneration. The purchase price of power from the cogenerator and the captive power plants is not fixed and varies from case to case. The purchase price of power is based on the marginal cost of generation. This prevents the cogenerator to invest in higher capacities unless the cogenerator is also paid the capacity charges. No fixed quantity has been specified for supply of power to the grid.

The power purchase price from the cogenerators should be based on GEB's current avoided costs. The avoided cost of generation in Gujarat currently varies between Rs. 2.40 to Rs. 2.60 per kWh. The avoided cost of transmission and distribution is Rs.

1.50 per kWh. Therefore the total cost of HT delivered power is approximately Rs. 4.50 per kWh.

5.8 Conclusion

The estimated cogeneration potential in the pulp and paper, cement, sugar and chemical & pharmaceuticals industries alone is over 400 MW, of which almost 300 MW can be exported to the GEB grid. This is a substantial amount of power, and will bridge the gap between the restricted and unrestricted demand.

However, in order to realise this potential of cogeneration, the policies of the GEB towards cogenerators, need to be modified and updated in order to encourage industries to set up cogeneration units and export the surplus power available with them to the grid.

Annexure 5.1: Theoretical Steam Rates at Commonly Used Steam Conditions

	Initial pressure, kg/cm² (gage)											
	10.20	27.21	40.82	40.82	57.82	57.82	85.03	85.03	98.64	98.64	122.45	163.27
	Initial temperature, °C											
	185.50	315.56	398.89	440.56	440.56	482.22	482.22	510.00	510.00	537.78	537.78	537.78
	Initial superheat, °CS											
	0.00	66.61	127.33	169.00	147.67	189.33	163.39	191.17	180.56	208.33	192.17	169.44
	Initial enthalpy, Kcal/kg											
	665.25	726.85	767.69	790.95	784.94	808.81	800.41	816.94	813.10	829.79	823.61	812.65
Exhaust pressure	Theoretical Steam Rates kg/kWh											
Hg (abs.)												
1.50	4.59	3.56	3.13	2.99	2.91	2.78	2.72	2.64	2.62	2.54	2.52	2.50
2.50	4.95	3.77	3.30	3.15	3.05	2.92	2.85	2.75	2.73	2.65	2.62	2.60
3.50	5.22	3.94	3.42	3.26	3.16	3.01	2.94	2.84	2.82	2.73	2.70	2.68
5.00	5.57	4.13	3.57	3.40	3.29	3.13	3.04	2.95	2.92	2.82	2.79	2.76
kg/cm2 (gage)												
0.00	8.81	5.72	4.73	4.46	4.24	4.00	3.82	3.68	3.63	3.50	3.43	3.37
0.34	9.86	6.16	5.02	4.74	4.47	4.22	4.01	3.86	3.80	3.65	3.58	3.50
0.68	10.90	6.55	5.29	4.98	4.68	4.41	4.17	4.01	3.94	3.80	3.71	3.63
1.36	13.01	7.28	5.76	5.41	5.05	4.74	4.45	4.28	4.20	4.03	3.93	3.83
2.04	15.31	7.96	6.20	5.80	5.36	5.04	4.70	4.51	4.41	4.24	4.12	4.00
2.72	17.90	8.63	6.60	6.15	5.66	5.30	4.92	4.72	4.60	4.42	4.29	4.15
3.40	20.91	9.28	6.98	6.50	5.94	5.55	5.13	4.91	6.15	4.59	4.44	4.29
4.08		9.95	7.35	6.84	6.21	5.79	5.32	5.09	4.95	4.75	4.58	4.42
5.44		11.30	8.09	7.52	6.72	6.26	5.69	5.43	5.27	5.04	4.85	4.66
6.80		12.75	8.83	8.20	7.21	6.71	6.03	5.75	5.56	5.31	5.10	4.88
8.50		14.74	9.80	9.10	7.83	7.29	6.44	6.14	5.91	5.65	5.38	5.13
10.20		17.06	10.83	10.06	8.46	7.88	6.85	6.52	6.25	5.97	5.65	5.36
11.90		19.84	11.95	11.10	9.11	8.48	7.25	6.91	6.59	6.29	5.92	5.59
13.61		23.25	13.18	12.25	9.79	9.11	7.65	7.30	6.92	6.61	6.19	5.80
17.01		33.31	16.09	14.95	11.26	10.49	8.49	8.10	7.60	7.26	6.72	6.22
20.41			19.87	18.46	12.95	12.06	9.37	8.94	8.31	7.93	7.25	6.63
27.21			32.82	30.45	17.30	16.10	11.36	10.83	9.84	9.39	8.36	7.46
34.01							13.77	13.12	11.60	11.07	9.57	8.31
40.82							16.83	16.05	13.71	13.08	10.94	9.22

Source: "Theoretical Steam Rate Tables - Compatible with the 1967 ASME Steam Tables." ASME, 1969

Annexure 5.2: Government of India's policy on cogeneration

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1. Introduction

Since the announcement of private power policy of the Government of India in 1991, a number of proposals, including proposals from foreign promoters, have been received through Independent Power Producer (IPP) route. However, as the gestation period for large power projects is long, it would be possible to complete very few projects in the near future and, therefore, we would face huge shortage of power. At the end of 1996-97, the energy shortage is visualised at 15% and peaking shortage at 30%.

It is, therefore recognised that there is an urgent need to open an alternative route, other than Private Generating Company, where the industries themselves will be interested to meet their own power demand by pooling resources together. Captive Power plants, because of the inherent benefits offered by them, were considered as one such alternative route. Accordingly, State Governments were requested to accord high priority to setting up of captive plants in their States and also encourage absorption of the available surplus power, to be generated in a captive power plant in the State grid at a remunerative tariff. A detailed guide line to this effect was issued through a letter to All Chief Secretaries of States from the office of the Secretary (Power), Government of India (DO No 6/1/Tariff/Captive Power/95, 9th October, 1995). Through a subsequent communication (DO No A-31/94-IPC dated January 30, 1996) regarding clearance process for captive power projects, it was clarified that the captive power plants of any other persons [including jurists persons and excepting generating companies] are not subject to the provision of Section 29 (2) of the Electricity (Supply) Act. Section 43(1) of the Act provides that the Board may enter into arrangement with any persons producing electricity within the State for the purchase of the power on such terms as may be agreed of any surplus electricity which that person may be able to dispose of. However, as per Section 44(2A) the Board shall consult the authority in cases where the capacity of new generating station, or as the case may be additional capacity proposed to be

created by the extension or replacement exceeds 25 MW. Hence, in terms of Section 44 of the Act, captive power/cogeneration plants require the approval of the State Electricity Board only. The Board has to simply refer the proposal to the Central Electricity Board only. The Board has to simply refer the proposal to the Central Electricity Authority for consultation, under Section 44(2A) of the Act, in cases where the capacity of the new generating station exceeds 25 MW. Ministry of Power, Government of India, identifying the need for some rationale for fixing of the tariff for the captive power plants had suggested setting up of an institutional mechanism allowing captive power units an easy and automatic entry into the stage grid and announcement of a mutually-agreed, rational rate of purchase of incremental power generated by the captive plants (not lesser than the variable cost of power and not greater than that allowed under the two part tariff notification).

It is generally recognised that industry in general and a process industry in particular needs energy in more than one form and if the energy requirements and supply to the industrial units are carefully planned the overall efficiency of a very high order is possible to achieve. With the combined objectives of promoting better utilisation of precious energy resources in the industrial activities and creation of additional power generation capacity in the system, encouragement to cogeneration plants in the country is being suggested.

2. Definition of Cogeneration

A cogeneration facility is defined as one which simultaneously produces two or more forms of useful energy such as electric power and steam, electric power and shaft (mechanical) power etc. Cogeneration facilities, due to their ability to utilise the available energy in more than one form, use significantly less fuel input to produce electricity, steam, shaft power or other forms of energy than would be needed to produce them separately. Thus by achieving higher efficiency, cogeneration facilities can make a significant contribution to energy conservation.

3. Objectives of the Policy

As electricity and heat are fundamental inputs to most of the industrial activities the present policy strives to achieve the dual objectives of achieving higher efficiency in fuel use in the industry as well as the availability of surplus electricity to the State grid, by combining power and heat generation for industrial use.

4. Process for creation of Cogeneration Facility

With a view to promote setting up of cogeneration plants, it is proposed that the industry having cogeneration potential would be allowed to develop a power generating facility

without necessarily going through the competitive bidding process, for projects of any size. In addition, in such cases the projects for the purpose of CEA clearance would be treated in the same way as any proposal for setting up of captive plant is required to be treated by the State Government under Section 44 of the Electricity (Supply) Act, 1948.

5. Cogeneration Plants

Two basic cogeneration cycles have been identified:

(i) **Topping Cycle:** Any facility that uses fuel input for power generation and also utilises for useful heat for other industrial activities. In any facility with a supplementary firing facility, it would be required that the useful heat, to be utilised in the industrial activities, is more than the heat to be supplied to the system through the supplementary firing by at least 20%.

(ii) **Bottoming cycle:** Any facility that uses waste industrial heat for power generation by supplementing heat from any fossil fuel.

6. Qualifying Requirements

A facility may qualify to be termed as cogeneration facility if it satisfies certain operating and efficiency standards which are explained below.

(i) Qualifying Requirements for Topping Cycle

The qualifying requirements for topping cycle would depend on the type of fuel used as the overall efficiency levels likely to be achieved for power generation varies with the choice of fuel. Essentially, any cogeneration facility meeting the efficiency requirement will be more efficient than any combination of separately generated electricity and steam using the state-of art-technology. As such while setting the efficiency standards, the achievable efficiency in case of a particular fuel has been kept in consideration. In addition, for all cases of cogeneration facility, it would be required that at least 20% of the total energy output is in the form of useful thermal energy.

As the cogeneration project would be feeding power to the state grid, in order to maintain grid stability and facilitate proper planning of the power system, it would be required that the

cogeneration facility must be available to supply at least 5 MW of power for at least 250 days in a year.

(a) Using coal as fuel

Assuming that the achievable thermal efficiency for power generation using coal as fuel hovers around 35% while the boiler efficiency for steam generation observed in Indian industries is about 90%, the efficiency standard set for any cogeneration facility is as under:

The sum of useful power output and one half the useful thermal output be greater than 45% of the facility's energy consumption.

(b) Using Liquid Fuel

Assuming that the achievable thermal efficiency for power generation using liquid fuel based combined cycle power generation system is about 50% while the boiler efficiency for steam generation observed in Indian industries is about 85-90%, the efficiency standard set for any cogeneration facility is as under:

The sum of useful power output and the useful thermal output be greater than 65% of the facility's energy consumption.

(c) Refinery Bottoms as fuels

Refinery Bottoms or those by products of refining process would be permitted to be used as fuel for cogeneration facilities to be set up by any petroleum refining unit which can not be easily marketed due to transportation problems or due to low heat content. However, to qualify as a cogeneration plant, *the sum of useful power output and one half the useful thermal output be greater than 45% of the facility's energy consumption.* And in any calendar year, not less than 90% of the total heat input for the facility should come from refinery residue or the refinery bottom. And in any calendar year, not less than 90% of the total heat input for the facility should come from refinery residue or the refinery bottom.

(ii) Qualifying Requirements for Bottoming Cycle

In case of bottom cycle, the total useful power output in any calendar year must not be less than 50% of the total heat input through supplementary firing.

7. Tariff fixation:

While fixing tariff from a cogeneration plant, the basic consideration would be to share the benefits of higher efficiency. In addition, the other advantage available to the industry is

availability of assured supply of power and possibly at a tariff lower than what the SEBs normally charge from their industrial consumers due to cross subsidisation. On the other hand SEBs also stand to benefit from the fact that they get surplus power at a rate lower than the marginal cost. However, in the bargain SEBs would have to let go some of their good customers. The tariff should, therefore, reflect these issues.

The tariff can be fixed by the SEB by making adjustments for the higher efficiency and applying the same on the marginal cost of generation. Accordingly, the SEB can notify an acceptable tariff, reflecting the modified marginal cost of generation and pay at the rate for the life of the plant barring major fuel price escalation.

Alternatively, the SEBs may chose to notify the first year tariff in two parts, fixed and variable, and announce an tariff escalation formula considering the fact that with the servicing of debt, recovered through depreciation, the fixed cost component comes down every year and at the same time the fuel cost increases due to fuel escalation.

However, realising the fact that ultimately the power sector would be required to move away from the cost based tariff structure, to get the full benefits we can probably use cogeneration plants for this switch over as even if there is slight error in fixing of the marginal tariff the damage would be very limited and can be corrected quickly in the subsequent cogeneration plants. This would also provide useful bench marks for other major IPPs.

In case of topping cycle plants using refinery bottom as fuel, the tariff would be fixed by the SEB on negotiated basis, providing for recovery of fixed costs of the power generating facility and the variable cost which could be determined by making adjustments for efficiency factors and other operational factors. Typically, the tariff for such plants may be represented by

$$\text{Tariff} = \text{FCC} + 0.8 * \text{Variable cost}$$

8. Procedure for Obtaining Qualifying Status

The qualifying Status to any facility would be granted by the State Government. The power producer would be required to submit the necessary documents to the State Government/SEB to establish fulfilment of the qualifying requirements in terms of efficiency criterion, choice of fuel, power generation technology and the stages of heat absorption in the industry.

9. Generation Schedule

As the availability of surplus power to be fed into the State grid will vary during the day depending on the operating cycle of the industry and may also vary with season if the industrial operations are season specific such as sugar mills etc. the power producer and the SEB/State Government would be required to mutually work out the schedule for power supply to the gird considering the industry and grid requirements.

(P. ABRAHAM)
Secretary to the Government of India

ORDER

Ordered that a copy of the Resolution be communicated to all concerned.

Ordered that the Resolution be published in the Gazette of India for general information.

(P. ABRAHAM)
Secretary to the Government of India

CHAPTER 6

CHAPTER 6
DSM program design

6.1 Introduction

In Chapters 1 through 5, various DSM measures specific to Gujarat have been discussed in detail. Various options have been presented such as peak shaving in the industrial (both HT & LT) and agricultural sectors, installation of energy efficient technologies, using electricity pricing as a tool for energy conservation, and cogeneration by HT industries to help meet the peak system load. In this chapter, the various options are synthesised into one whole, and a plan is presented to facilitate the implementation of the various options of Demand Side Management.

6.2 Recommendation of EETs to be targeted

A detailed analysis of various energy efficient technologies (EETs) considered for Gujarat, has been carried out in Chapters 2 and 3. Upon studying Tables 2.4 and 3.3, it was found that there are five EETs which are ranked in the best ten both from the point of view of customer acceptability and energy saving potential. These five EETs are listed below.

1. Replacement of 40 W tubelights with 36 W tubelights in the industrial sector.
2. Replacement of standard efficiency ceiling fans with high efficiency fans in the domestic sector.
3. Replacement of standard efficiency motors with high efficiency motors in the industrial sector.
4. Replacement of standard efficiency pumps with high efficiency pumps in the industrial sector.
5. Replacement of magnetic ballasts with electronic ballasts in the industrial sector.

Even though the EETs listed above pertain to specific sectors, most of them can be applied in all the consumer sectors. For example, replacement of 40 W tubes is a zero cost option, and should be targeted towards all the customers of GEB. Similarly, there is not much additional cost in enlarging the targeted consumer categories from domestic to all, in the case of ceiling fans. In the case of replacement of magnetic ballasts by electronic ballasts, only the commercial sector besides the industrial, may be amenable to this EET given the subsidised tariffs for domestic consumers.

6.3 Barriers and constraints to implementation of EETs

6.3.1 General barriers

There are many barriers and constraints which need to be addressed before the identified EETs can be implemented with any degree of success. The important barriers are:

1. **Lack of information:** Usually it is seen that consumers have very little knowledge or information on energy efficient equipment and appliances available in the market. In the case of domestic appliances and lighting equipment, even the shopkeepers are largely ignorant about the energy consumption characteristics of the equipment sold by them.

2. **Consumer apathy:** Customers, especially in the domestic, commercial, and agricultural sector, have little knowledge of the efficiency of most appliances they buy and their impact on power consumption and energy costs.

3. **Subsidised electricity prices:** Tariffs paid by the domestic and agricultural sectors do not reflect GEB's true cost of supplying power. Thus they have little incentive to consider buying energy efficient equipment.

4. **High personal discount rates:** Customers usually have a very high personal discount rate which translates into them requiring very short payback period on investments on energy efficient equipment. Most domestic and commercial customers may require payback of less than a year. Even large industrial customers usually restrict investments to equipment with payback of under 3 years. Few customers conduct life-cycle studies to make investment decisions.

5. **Insufficient capital:** Most energy-efficient equipment are priced higher than standard efficiency equipment. Customers generally lack the initial capital required to finance purchase of energy-efficient equipment.

6. **Availability of EETs:** Efficient equipment and appliances are not always readily available in all regions, even in urban environments. Industrial equipment may have to be custom ordered in order to work with specific pieces of existing machinery.

7. **Lack of faith in EETs:** Consumers have little faith in the claims of energy efficiency made by the manufacturers. They are unwilling to invest in a new technology unless the benefits are demonstrated to them and/or their peers are using the same.

8. **Reliability of equipment in local conditions:** Energy efficient equipment used in the developed countries may be especially sensitive to the quality of power supplied and may not tolerate large deviations in voltage and/or frequency.

6.3.2 Barriers specific to the identified EETs

1. <u>Replacement of 40 watt tubelights with 36 watt tubelights:</u> The major barrier to this measure is lack of awareness amongst consumers regarding its energy saving potential. Also, there may be a misplaced apprehension that switching to the energy efficient alternative would result in reduced light output.

2. <u>Replacement of standard efficiency ceiling fans with high efficiency ceiling fans:</u> The difference in the initial cost of fans manufactured by the unorganised sector and those manufactured by the larger companies, as well as consumer apathy towards energy conservation are the major barriers.

3. <u>Replacement of standard efficiency motors with high efficiency motors:</u> The main barrier to the implementation of this measure is the higher cost of the high efficiency motors and lack of consumer awareness regarding their energy saving potential.

4. Replacement of standard efficiency pumps with high efficiency pumps: While the incremental cost of a high efficiency pump is moderate, consumers are averse to spending the extra money as energy efficiency is not a priority area with them.

5. Replacement of magnetic ballasts with electronic ballasts: The electronic ballasts are very costly compared to the magnetic ballasts. Also, the initial ones to be sold in India did not perform very well, with the result that consumers are wary of using them. Another problem with electronic ballasts is their sensitivity to the quality of power supplied.

6.4 Methods to overcome customer barriers

There are a number of ways in which the barriers to energy efficiency discussed above can be addressed. The more important ones are discussed below.

- Information campaigns
- Energy audits
- Codes, standards and labelling
- Co-operation with other stake holders in a DSM program
- Innovative tariffs and financial incentives
- Training
- Demonstration projects
- Market transformation

6.4.1 Information campaigns

There are several approaches GEB could consider to impart information on energy efficiency to customers.

- **Organise energy efficiency exhibits at conferences, trade fairs, etc.:** Display of energy efficiency equipment could be arranged by GEB, in co-operation with various trade organisations and manufacturers, conferences and trade fairs related to energy, lighting, domestic appliances, industrial equipment, etc. Brochures and pamphlets on energy saving devices can be made available to exhibitors and visitors.

- **Establish energy conservation centre(s):** A permanent centre for display of energy efficient equipment could be set up by GEB where consumers can see and compare for themselves the performance of standard efficiency and high efficiency equipment at one location. At least one centre each should be established in the major cities to begin with, and then the concept could be expanded to cover the entire state.

- **Develop a database of manufacturers of energy efficient equipment:** A directory should be developed which, besides giving the list of manufacturers of EETs, also list the commonly used standard efficiency equipment and suggest suitable replacements, and also give information on the price premium and other advantages like increased life, enhanced performance, etc. if applicable.

6.4.2 Energy auditing

While GEB already offers energy auditing services through its energy conservation cell to industrial customers, the service should be expanded to cover the other customer classes also. GEB could also maintain a list of private firms who are qualified to carry out energy audits, refer customers to them.

Ideally, these energy audit firms should be licensed by the GEB or the state government, maybe through the universities, and the energy auditors could undergo a certification program. The certification program could be managed by the local chapter of the Institution of Engineers (India).

6.4.3 Codes, standards and labelling

- **Efficiency standards:** Gujarat Electricity Board should work with appropriate state and central government agencies such as the BIS and GEDA, and others to develop efficiency standards for appliances and equipment.

- **Codes:** GEB could consider developing codes and procedures to specify energy efficient equipment in buildings and industry. These codes could specify the maximum energy consumption per unit area of a building, for example.

- **Labelling:** GEB could encourage the establishment of a labelling program for major energy-using products, equipment and appliances where performance parameters and energy consumption are prominently displayed to help customers make investment decisions. The information on the labels should be standardised across competing brands to enable consumers to make a quick comparison.

6.4.4 Trade ally co-operation

For a DSM program to succeed, the different trade allies have to actively co-operate with each other. GEB could consider launching joint advertisement campaigns with the manufacturers of energy efficient equipment to educate people about the advantages of using EETs. For example, GEB and the manufacturers of compact fluorescent lamps (CFLs) could come together under one banner to inform the public of the benefits of a CFL over an incandescent lamp.

On their part, the manufacturers of EETs could bear the burden of providing a part of the rebates and other financial incentives offered to consumers to offset the costs incurred by GEB in the advertisement campaign.

All parties stand to win from this arrangement. GEB would benefit by reducing the energy demand on its system, the manufacturers would benefit by increased sales, while the consumers would benefit by reduced electricity bills and improved performance of the EETs.

6.4.5 Innovative tariffs and financial incentives

There are a number of innovative tariff options which GEB could consider implementing, the chief among them being Time-of-Use (TOU) tariffs. TOU tariffs have higher charges for energy consumed during the utility's peak hours than during the off-peak hours. This differential encourages customers to either shift some of their electrical load to off-peak periods, or install energy efficient equipment to replace the devices being used during peak hors, or both.

GEB can also consider offering financial incentives for the installation of energy efficient equipment in order to break the first cost barrier. These incentives could be in the form of outright rebates or grants towards the cost of purchasing EETs or soft loans with low interest rates. Domestic and agricultural consumers may be targeted by the former method, while commercial and industrial customers by the latter.

6.4.6 Training

GEB could consider conducting training programs for its customers on enhancing energy efficiency. Simple measures like keeping the refrigerator outside the kitchen or shading an air-conditioner can provide energy savings without incurring any financial costs. GEB's own engineers could also be trained so that they are able to offer advice and tips on saving energy to consumers.

6.4.7 Demonstration programs

Demonstration programs are a must to encourage installation of energy efficient technologies. For a start, GEB should upgrade the equipment used in all its own offices, as it must take the lead in setting an example. Visitors to GEB's offices would also be able to observe and appreciate the EETs for themselves if this is done.

Incentives can be provided to large commercial complexes or hotels to upgrade their equipment, and then serve as show-pieces to the rest of the community. The same strategy can be followed in the industrial sector.

The demonstration programs should follow strict documentation of the level of energy consumption before and after the installation of energy conserving equipment, so that the energy savings can be documented and authenticated, being backed up by accurate figures of electricity consumption.

6.4.8 Market transformation

There are various ways in which GEB can transform the market. It could work with manufactures to phase out standard efficiency equipment over time. For example, 36 watt 4-feet fluorescent tubes have been around for a long time now, offering almost the same light output as the 40 watt ones. If GEB could convince the lamp manufacturers to discontinue the supply of 40 watt tubelights, a lot of energy could be saved.

The same objective can also be met through legislation where the government disallows the manufacture and sale of standard efficiency equipment for which higher efficiency alternatives are available. This option has been followed in the United States of America, where manufacture of selected inefficient lighting equipment has been banned under the Energy Policy Act of 1992.

6.5 Role of different agencies in promoting DSM[1]

The successful implementation of a DSM program involves the support and active participation of a number of allies. The list of allies, besides the state electricity board, includes the government, manufacturers, distributors, retailers, trade associations, contractors, etc.

The first and foremost ally is the government. Government support will be required in the development and enforcement of energy efficiency codes and standards. Unless adherence to the codes and standards is made mandatory by law, they are usually not even worth the piece of paper they are written on.

The private sector has to co-operate with utilities in implementing energy efficiency options. Consulting and contracting firms have to contribute not only in the implementation process but they have to also provided support in program development. Energy service companies (ESCOs) have to participate in the delivery of energy efficiency through direct program support. Equipment manufacturers and suppliers have to work in co-operation with utilities to provide energy efficient products and equipment and maybe agree to voluntary product labelling giving information on energy consumption.

6.5.1 Role of the government

The government has a very important role in supporting utility DSM initiatives. DSM can be motivated simply by utility economics to improve the system load factor and reduce revenue losses. However, DSM should be supported through government regulation, providing incentives to utilities to adopt integrated resources planning.

[1] "*Study of DSM Options, Role of MSEB, Analysis of DSM Options*", SRC International, Tata Energy Research Institute, Ontario Hydro International, August 1995.

The government should consider allowing the utility a higher rate of return for DSM programs which are capitalised in the rate base. It also should authorise the electricity board to implement cost-based tariffs and introduce IRP as the basis for power sector planning.

One of the strongest incentives for energy conservation on the customer's side of the meter is cost based electricity prices. Subsidised electricity prices distorts conservation, it lowers the customer's total electricity bill and provides a disincentive for adopting energy efficiency measures.

The government could also take an active role in the promotion of energy efficiency which could include all forms of energy. They can launch information campaigns targeting increased awareness and interest with energy users. The government could also provide low cost financing and possibly fund research development and demonstration projects.

Development of codes and standards for new building construction provides a good example of how the utility and the government could co-operate to better energy efficiency levels.

The utility and government often have different but complementary objectives in building codes. The utility is interested in the delivery of DSM measures and the government usually wants to maximise the societal, environmental and energy benefit, and ensure consumer protection.

The key to successful development of DSM programs in new construction is to achieve both of these goals through a co-operative approach. The first hurdle is to convince the government that an incremental improvement in energy efficiency would result in a benefit to society. The next step is to provide current design practices and the necessary data for an efficient design.

6.5.2 Role of equipment manufacturers, distributors and retailers

Equipment manufacturers also have a key role in DSM programs. Gujarat Electricity Board, through the Gujarat State Government must ensure they will have a good supply of quality energy efficient equipment to meet their program demands. Manufacturers are often reluctant to design and build new products without a proven market with sufficient volume to help bring down costs and prices. GEB must work closely with manufacturers not only to get the right products on the market, but also to co-ordinate joint promotions and share market research information to achieve sales target.

The needs of distributors and retailers must also be considered in a good program design. Retailers and distributors have a direct influence over the customers purchase decision. They must stock and display the energy efficient products and be well trained in presenting their features and benefits.

6.5.3 Role of contractors, architects, consultants

Trade allies will be an important resource to any DSM program. The specific role of the allies should be designed into each program. They could be simply consulted at the program design stage or be active partners in the delivery and implementation of the programs.

In contracting out any direct customer contract work with allies the utility should be careful to maintain some element of quality control over the work. Pre-certification of allies and equipment suppliers are recommended.

In the delivery of DSM programs many utilities have established working relationships with the design and building communities. Greater co-ordination between the builder, designer and owner is believed to be a key factor to better buildings in terms of energy efficiency. Along with training and technical assistance, utility staff could participate in builder's associations.

6.5.4 Co-operation with other SEB's

There are a number of benefits in developing comprehensive joint programs with a number of SEB's pooling their resources. Together they represent a larger customer base that will gain the attention of the manufacturing and consulting community. A co-ordinated utility approach is often beneficial in the area of developing codes, standards, labelling of appliances and setting equipment efficiency levels. Joint communication campaigns, brochures, media advertising and market research are all areas where a joint utility effort will be cost efficient.

6.5.5 Role of ESCO's

Energy service companies (ESCO's) can effectively deliver long term, dependable energy saving projects that are financed directly through the cash flow from the savings.

The ESCO is in the business of identifying energy efficiency opportunities, designing a retrofit, implementing the design, financing the implementation, managing the construction, and monitoring the performance of the retrofit. ESCO's can do all or only a portion of the above functions within any utility DSM program. GEB can use ESCO's to quickly implement DSM at a lower risk since the performance of the retrofits are guaranteed by the ESCO.

6.6 DSM program implementation in the domestic and commercial sectors

The domestic sector and commercial sectors offer good DSM potential, and measures usually apply to large groups of customers which helps to facilitate the program delivery. Thus DSM programs targeting these sectors are an excellent way for GEB to communicate to the general public that they are promoting energy efficiency which also helps to improve their customer image. The network of allies is also very important. This includes manufacturers, distributors, contractors, consultants, architects, and government.

A long term approach is recommended with four different market approaches; a public relations campaign to increase customer awareness, joint promotions with suppliers and retailers, the use of regulation through codes and standards and direct installation of measures by GEB.

The DSM measures to be targeted at these two sectors are the installation of 36 W tubelights in place of 40 W tubelights, replacement of standard efficiency ceiling fans by high efficiency ceiling fans, and replacement of magnetic ballasts by electronic ballasts. The last measure may only be adopted by the commercial sector because of the high incremental first cost of the EET, but even then, it could be offered to both the sectors.

6.7 DSM program implementation in the industrial sector

The industrial sector demands a very technical and business oriented approach. GEB should take into consideration the availability of capital and an industrial purchasing cycle which could be as long as two years.

The specific EETs with which GEB should target the industrial customers are:

1. Replacement of standard efficiency motors with high efficiency motors.
2. Replacement of standard efficiency pumps with high efficiency pumps.
3. Replacement of 40 W tubelights with 36 W tubelights.
4. Replacement of magnetic ballasts with electronic ballasts.

6.7.1 High efficiency motors

Segmentation by technology is often beneficial. For example, motors typical account for about 70% of industrial electricity consumption, of which an estimated 80% is consumed by fan, pump and blower systems. Concentrating on industries that are either growing or retrofitting for competitive reasons is also important. These companies are predisposed to investing in the future, and so GEB can help customers upgrade to the energy efficient alternative.

A high efficiency motor (HEM) program can be cost effective when the customer is purchasing new or replacement motors. High efficiency motors currently represent a negligible portion of the current sales. With this very low market share it is very likely that financial incentives would be required. A HEM program design should encourage motor manufacturers to produce the motors, the distributors to stock them and offer a relatively smaller price differential to encourage customers to buy them. Often customers need replacement motors on very short notice and they must be readily available with the local distributors.

A dual rebate can be most effective, offering an incentive (or rebate) to the manufacturers to produce the motors and a distributor incentive to sell the motors. There will be some increased cost in stocking both standard and HEM motors during the initial phases of the program. Developing a strong relationship with the motor distributors is very important as they interface directly with the customer and often affect the purchasing decision.

6.7.2 High efficiency industrial pumps

An industrial performance optimisation program should be considered for energy savings in pumps. Significant savings can be achieved when these are optimised to more accurately meet process demands.

In order to achieve these savings, it is recommended that GEB develop programs that address the individual needs of the customers. This is best achieved by offering a series of programs that lead the customer through their decision process. This would include an energy audit program to identify the opportunities, a feasibility assistance program to provide a cost benefit analysis for the selected measures, followed by a financial incentive program designed to give the customers a good return on their investment.

6.7.3 High efficiency lighting program

Lighting is usually not considered a high priority area in industry. Industry should be educated about the benefits of high efficiency lighting through an information campaign. Materials and maintenance managers should be encouraged to specify 36 watt tubelights instead of 40 watt tubelights for all areas. Electronic ballasts will be cost effective in areas where lights are used for longer hours. Additional benefits such as elimination of flicker and humming, and quick start of the lamps should be high-lighted.

6.7.4 Industrial load shifting

With an objective to improve the system load factor, GEB should focus on TOU rates to encourage load shifting and valley filling with the large industrial customers. This will require a very targeted program working closely with the large industrial customers, completing detailed studies of their energy use and operating flexibility considering the possibility of increasing production capacity and adding product storage.

Low tension industrial customers can also be targeted for a load shifting program as discussed in Chapter 1. GEB will have to work closely with the management of the industries and convince them of the need to shift their working times in order to improve the system load factor. GEB may have to consider offering financial incentives to encourage industries to shift loads.

6.8 DSM program implementation in the agricultural sector

As has been brought out from the analysis of the energy efficient technologies in Chapters 2 and 3, no specific EETs are to be targeted at the agricultural sector initially. Since this sector is highly resistant to change, GEB should concentrate on marketing the EETs to the other sectors.

However, the agricultural sector is a good candidate for load shifting in order to improve GEB's system load factor as discussed in Chapter 1.

6.9 Marketing and delivery mechanisms

6.9.1 Public relations/communication campaign

A public relations program should develop a customer focused image including the development of an energy efficiency identity. This plan should begin to build strong working relationships with major allies including manufacturers, retailers and contractors to promote common initiatives.

The public relations program should focus on GEB's objective to reduce their customer's cost and improve the quality of life by offering information and special promotions in conjunction with suppliers. The message should increase customer awareness of energy efficient products and how they will benefit the customer in addition to energy savings. This may include increased comfort, aesthetics, care of the environment, quality construction and the ability to control energy bills.

6.9.2 Joint promotion/marketing programs

Joint promotion programs with the manufacturers and retailers for domestic and commercial lighting products and fans are advised. This could include GEB outlining the customer benefits and possibly provide rebate coupons to reduce the financial burden of consumers willing to invest in efficient technologies. The manufacturers should ensure that the products are available and provide point of purchase displays and could possibly support the rebates. Major retailer's should be encouraged to stock the products, feature them in local advertising and commit to displaying the products in the specially designed displays.

To promote energy efficient appliances GEB should consider developing an awareness program that provides energy ratings which are clearly displayed on each appliance giving its average monthly energy consumption or efficiency rating. This would require working with suppliers for testing to establish energy ratings and labelling of all appliances to be sold. Rebates to appliance retailers to help encourage the sale of the improved models and incentives to manufacturers to incorporate more-efficient designs in their production. Retailer training should also be considered so they can promote the efficient features of the appliances to prospective customers.

6.9.3 Codes and standards

In addition to the above, GEB should work closely with the government to develop codes and standards for minimum efficiencies on domestic and commercial appliances. This work should be done in consultation with the local manufacturers to ensure that they can produce the desired products and have sufficient time to get them on the market.

In parallel, it will be important for the Government to set up an independent lab for testing and certifying the energy efficient products.

Specifying building codes for the commercial sector is another important area where GEB should co-ordinate with the government. Specifying energy efficient equipment in original building designs is much more economical than retrofitting the buildings latter. This could include lighting, air conditioning, and building envelope design for lower air-conditioning costs.

6.10 DSM organisation structure

The DSM organisation structure must report as high as possible within the utility to be considered strategically equal with traditional supply options. GEB already has an energy conservation cell, which could be upgraded to function as a full fledged DSM department.

It is recommended that a Demand Side Management department be created at the General Manager level. The DSM group should be staffed by full-time staff. Initially it is recommended that divisions be set up in the following areas, recognising that the organisation of the group will evolve over time:

- Public Relations/Communications
- Market research, technical assessment, planning, program evaluation
- Program design and implementation
- Industrial sector
- Commercial sector
- Domestic sector
- Agricultural sector
- Sales

Assigning program managers for each major program is recommended. The program manager would be responsible to organise all the resources required to design, launch and monitor the program. This will include the development of relationships with major allies, including manufacturers, distributors and trade associations.

In the program development process cross functional teams should be used including sales and program evaluation staff along with the program manager. This will help ensure the success of programs from conception through to implementation and program evaluation.

The sales staff would be assigned to develop key customer accounts for large commercial and industrial customers. They should also develop strong working relations with local allies including equipment suppliers, consultants, contractors, etc. The sales staff will require extensive training in, energy efficient technologies, financing and multi-level selling.

6.11 Targets and time-frame for DSM program implementation

It is important that the DSM program outlined in this report is implemented in a time bound manner for it to realise its full potential. As far as possible, the targets, once set, should be considered sacrosanct, and no efforts spared to achieve them. At the same time, it is also necessary that the targets set should be achievable, as impossible targets may lead to frustration and despair, and resentment in the program implementation team. Keeping this in mind, the time-frame for various activities suggested here is indicative, and if necessary, should be modified to suit the requirements of the Gujarat Electricity Board.

The first milestone in the implementation of the DSM program is the setting up of a full fledged Energy Management Cell. It is suggested that this be done within a year of acceptance of this report.

Once the Energy Management Cell has been constituted and starts functioning, its first two tasks would be to launch information campaigns on energy efficient technologies and good housekeeping practices, as also to take steps for establishment of energy service companies (ESCOs) throughout the state.

The ESCOs will need to be trained on carrying out energy audits of consumer facilities, and also to recommend energy saving alternatives to replace existing equipment. The ESCOs will be GEB's link to consumers, so it is important that they are also taught inter-personal skills. It is suggested that within 12-15 months of the establishment of the Energy Management Cell, at least one ESCO should be functioning in every district headquarters, as also every major town of Gujarat. If need be, GEB can take assistance from the Energy Management Centre (EMC), Ministry of Power, in the establishment of ESCOs, as EMC has extensive experience in the same.

Once the ESCOs are established, GEB should target to achieve the penetration levels indicated in Table 6.1 every subsequent five years.

Table 6.1: Market share targets for identified EETs

			Targeted market share (of total equipment population) in n[th] year after establishment of ESCOs			
Existing Technology	Proposed Technology	Sector	5 years	10 years	15 years	20 years
Ceiling fan	Efficient fan motor	Dom	34.68%	45.52%	48.71%	49.63%
Magnetic ballast	Electronic ballast	Ind	7.84%	24.80%	31.18%	32.64%
Std. eff. Ind. pumps	High eff. Ind. pumps	Ind	79.04%	95.13%	98.26%	98.86%
Std. eff. motor	High eff. motor	Ind	59.74%	74.34%	77.29%	77.86%
TL Fluorescent	TLD Fluorescent	Ind	79.41%	95.99%	99.23%	99.85%

6.12 DSM program implementation costs

GEB will incur costs, both direct and indirect, in order to implement the outlined DSM program. The direct costs are related to the actual administration and monitoring activities with regard to the DSM program. These would vary depending on the actual staffing of the Energy Management Cell, and on the level of seniority of officers deputed to work for the Cell.

The indirect costs are related to the potential revenue loss due to reduced energy usage by the consumers in the targeted sectors. Since GEB is currently unable to meet the energy requirement in its service area, some amount of the revenue loss would be recovered from the sale of the energy saved, it would be difficult to recover the entire amount, as indicated in Table 6.2. This is so as the energy savings are mostly expected from the industrial sector, which pays the highest tariffs, and the sale of the saved energy would be in approximately the same ratio as the current energy consumption, with agriculture sector taking a major share.

The potential revenue loss to GEB is calculated and shown in Table 6.2. The calculations are based on the assumption that all the savings potential has been realised, and that the saved energy is sold in the same ratio between different sectors as the current energy consumption in GEB's service area.

Table 6.2: Revenue loss calculations

Revenue loss due to reduced sales of energy			
Sector	**Annual savings (GWh)**	**Avg. tariff (Rs/kWh)**	**Revenue loss (Million Rs/year)**
Industry	205.80	2.19	450.702
Domestic	36.16	1.06	38.330
Total annual revenue loss			*489.032*
Revenue earned from sale of saved energy			
Sector	**Annual sales (GWh)**	**Avg. tariff (Rs/kWh)**	**Revenue earned (Million Rs/year)**
Domestic	23.69	1.06	25.111
Commercial	14.52	2.68	38.914
Industry	100.68	2.19	220.489
Agriculture	103.07	0.19	19.583
Total annual revenue earning			*304.097*
Annual shortfall in revenue in million rupees			***184.935***

From Table 6.2, it can be seen that GEB stands to undergo a revenue loss of almost 185 million rupees annually. This would not happen if the agriculture tariff is revised to bring it in accordance with the actual cost of supply.

Since GEB is likely to incur an overall reduction in revenue inflow, no rebates for the EETs are suggested at this time. Also, it is felt that if rebates are offered, consumers may switch to using EETs for availing of the rebates, but revert to using the old and inefficient technologies once rebates are discontinued. A DSM programme without rebates would ensure that participating consumers do so because of the inherent savings potential of EETs, and not because the utility is subsidising the initial cost of EETs.

6.13 Conclusion

This chapter has presented a DSM plan which could be implemented by the Gujarat Electricity Board to encourage energy savings and enhance its system load factor. The fact that enough resources may not be available to do everything may not be available, and a few target areas have been identified to be the main thrust of the program in its ini. l stages.

It must be recognised that a DSM program is dynamic in nature, and its structure and thrust must evolve with the changing needs of the utility and its customers. The program must always keep moving and grow with time, and above all reflect the aspirations of all stake-holders if it is to prove successful.